Grey Water Contamination from Pleasure Boats in Ontario Lakes and Rivers

Report to

Ontario Ministry of the Environment

February 1987
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PLEASURE BOAT GREY WATER STUDY - FINAL REPORT

Dear Sir:

Enclosed are twelve copies of our final report on solutions to the problem of grey water discharges into Ontario recreational waters from pleasure boats. Two copies of the Appendices are also enclosed.

It is intended that the report will be used as a guideline for carrying out further studies to determine how best to protect Ontario's recreational waterways.

Our appreciation is extended to the Ministry of the Environment staff for their co-operation and contributions throughout the program.

Yours very truly,

for R. T. Staton,
Project Manager.

G. A. Aldworth, P. Eng.,
Project Director.

MS

Encls.

ABSTRACT

This study investigates the bacterial and chemical effects of discharging grey water (i.e. non-human wastewater) from pleasure boats into the receiving recreational waters of Ontario.

A review of literature published in Canada, United States, and Europe relating to grey water characteristics and quantities is carried out. This forms a basis for determining likely loadings and effects of grey water discharges from pleasure boats.

Recreational boating densities and use in the smaller inland and larger (Great Lakes) waterways of Ontario are considered, together with current pollution control regulations and concerns of affected groups.

Boat plumbing system variations are anlaysed for various categories of vessels, and retrofitting provisions to reduce grey water impact on receiving waters are developed. Cost estimates for modifications to existing and new boats are included.

Alternative solutions are identified and evaluated. The more promising solutions are discussed in detail relative to impact, practicality, regulation, and cost.

Recommendations on the approach, implications, implementation, and timing of proposed solutions are presented, as well as requirements for follow-on studies and monitoring programs.

Results of these investigations indicate that bacterial contamination of recreational waterways from grey water discharges is a significant factor under certain conditions. There has been a recent increase from houseboats whose use is proliferating - especially on inland waterways.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance and support offered by Ministry of the Environment staff throughout the course of this study, particularly Mr. D. Birnbaum and many personnel in the various regions.

The contribution of Dr. M. Brandes in the important area of contamination potential from grey water is particularly noted.

The input of Mr. J. Richardson MNR is also acknowledged, together with that of other provincial and federal ministries.

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1.0 INTRODUCTION

1.1 GENERAL

This report presents the results of investigations into the impact on Ontario's recreational waters of grey water (from kitchen, wash basin, shower, bilge, etc.) discharged from various types of pleasure boats.

There has been a substantial increase in the number of pleasure boats using Ontario lakes and waterways, particularly larger rental houseboats. In sensitive inland areas such as the Trent-Severn Waterway, this has resulted in heightened public concern regarding impairment of these recreational waters. This concern is documented by numerous articles in newspapers and complaints to government authorities. It is likely that increasing promotion of rental houseboat vacations and continuing purchases of privately-owned recreational boats will expand the problems associated with pleasure boating, and aggravate public concern.

1.2 GREY WATER QUALITY AND QUANTITIES

An extensive review of literature dealing with pollution effects of pleasure craft and related wastewater discharges was carried out. Most literature was directed towards examination of black water (human wastewater) which has to be retained in holding tanks on both commercial and pleasure craft with overnight accommodation facilities. Documentation on grey water from boating sources, on the other hand, was less penetrating, and generally pursued quantity rather than quality of grey water which is discharged directly to recreational waters.

In order to determine the characteristics and potential for bacterial and chemical contamination of receiving waters by pleasure boat grey water, literature dealing with grey water characteristics and quantities in similar settings was closely examined. Results of this review were used as a basis for establishing characteristics for boat grey water. In addition,

quantities of grey water discharges expected for various boat types were determined by discussions with boaters, houseboat rental companies, boat builders, and so forth.

Results of investigations into grey water characteristics indicate that a relatively high level of bacterial and chemical pollution can occur, particularly under certain conditions. Detailed discussion of grey water characteristics is presented in Chapter 3.

1.3 TRENDS AND CONCERNS

It is apparent that there is a current trend to increased recreational boating in Ontario as evidenced by recent extensive construction of mooring and launching facilities. For instance, a new 250-boat marina in Toronto Harbour will be completed in 1986, and two additional marinas having a capacity of up to 700 boats are intended in the near future for the Toronto area. It is reported that sales of new boats at the recent 1986 International Boat Show was greater than in 1985. Additional houseboat rental units are scheduled to be available for the 1986 season in areas such as Lake of the Woods, the Trent-Severn Waterway, and the Rideau Canal.

Concerns arising from increasing boating activity are expressed by a wide range of the public including swimmers, cottagers, fishermen, other boaters, environmentalists, and so forth. These relate to the perceived contamination of receiving waters, and to aesthetic effects as well. Related aspects such as the "invasion" of hitherto quiet rivers and bays also cause concern to local residents.

In view of these perceived problems associated with widespread boating in Ontario, it is appropriate to examine the pleasure boating scene to determine if pollution problems exist and, if so, develop suitable solutions.

2.0 PLEASURE BOATING

2.1 DESCRIPTION OF ONTARIO WATERWAYS

The Great Lakes, their tributary rivers, and Ontario's inland lakes make up the largest fresh water system in the world. These waters have provided "Highways" of exploration and commerce for centuries. Water from the Great Lakes slakes the thirst of one-third of the population of Canada, as well as a goodly populace in northerly U.S.A.

The area of the Canadian portions of the Great Lakes and related Ontario waterways is estimated to be over 100,000 km^2, of which 90% is accessible to recreational boaters (see Figure 2.1). The rugged, rocky bluffs on Lake Superior's north shore, the white sand beaches and secluded anchorages of Georgian Bay, and the combined natural and man-made waterways such as the Trent and Rideau Canal systems, provide a wide range of desirable landscapes and conditions for boaters.

A broad range of facilities are available to boaters throughout Ontario. In larger urban centres such as Kingston and in many smaller towns such as Midland, extensive amenities are available. By contrast, boaters have the option of visiting quiet lakes and bays in inland waterways, Georgian Bay or the Thousand Islands area where little or no commercial development has occurred.

Since much of Ontario's waters is relatively uncongested, many U.S. visitors bring their boats across for weekends or for an extended cruise during the summer. Power cruisers are the most common type of boat visiting from adjoining states and the tendency is to seek out protected harbours and waterways where most support facilities are available (fuel, shore power, potable water, provisions, etc.)

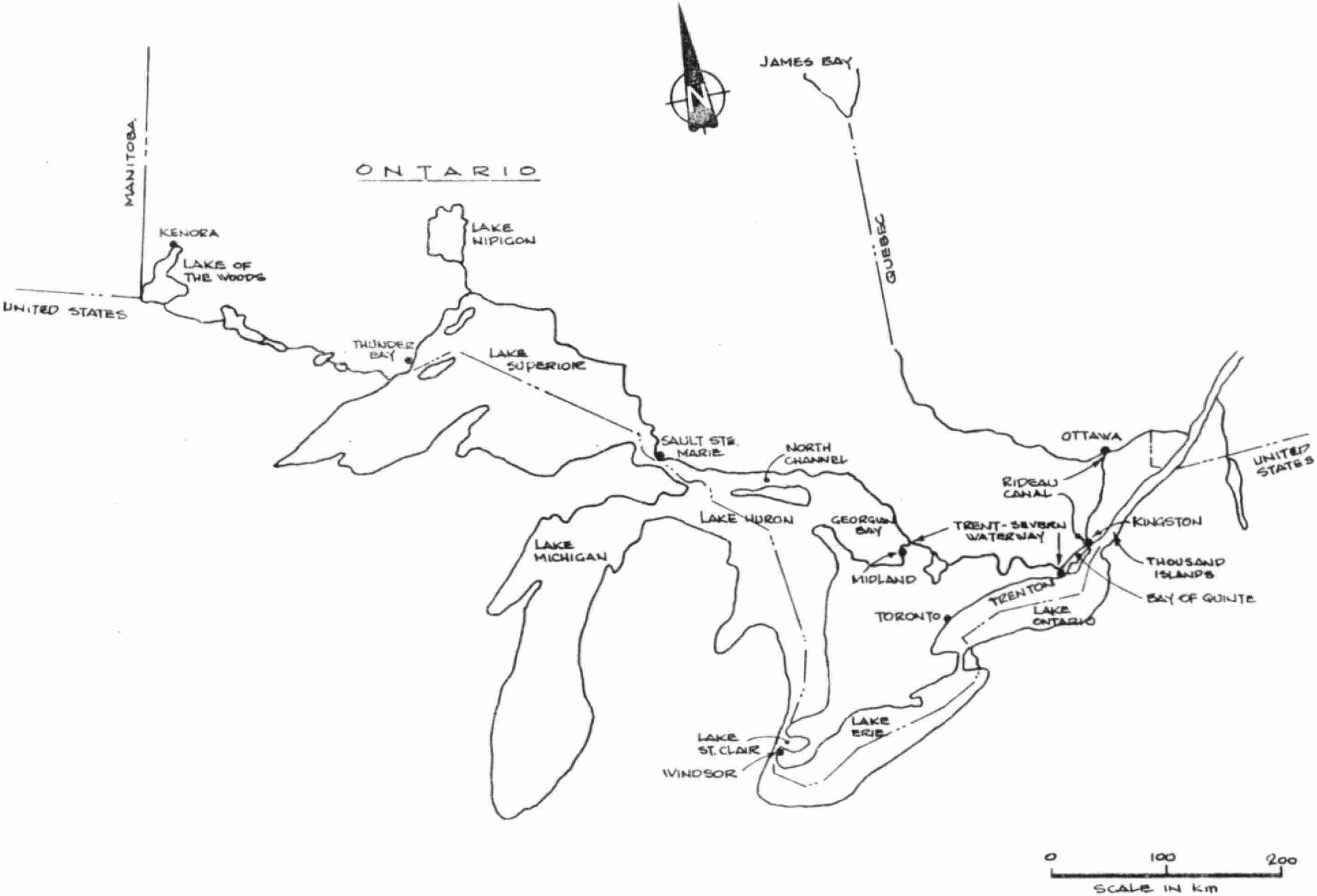

Figure 2.1 ONTARIO WATERWAYS

The Great Lakes and the St. Lawrence River provide important commercial routes for Canadian and international shipping carrying Canadian and American raw materials and finished products to and from all parts of the world. Pleasure boat and large commercial shipping uses of Ontario's waters normally do not conflict since the areas used for recreational activities are generally removed from the commercial routes. Some smaller commercial operations such as day-tours and houseboat rentals share the waterways with private pleasure vessels but represent a small percentage of overall users of recreational waters.

2.2 RECREATIONAL BOATING STYLES

The vastness of the Great Lakes, and the abundance of protected inland lakes and waterways in Ontario, provide ideal settings for the enjoyment of these waters by both land-based residents and recreational boaters, however the different lifestyles of boaters travelling the waterways and those on shore can conflict.

It is evident that the number of privately owned boats is increasing in Ontario as previously noted under Item 1.3. This is confirmed by on-going expansion of new docking facilities around the lakes and inland waterways such as the Trent-Severn Canal System. Indeed, one of the primary concerns of a boat-owner is obtaining a mooring space, particularly in the high season.

Many recreational vessels are of smaller size - under 6 m - which can be stored ashore and trailered to a convenient launching ramp for use during the weekend. These smaller boats typically do not have overnight accommodation, so are used for daily routings involving sailing, swimming, picnicing, fishing and so forth.

A recent development is the increasing use of larger houseboats, often in the protected waters of small lakes and interconnecting waterways. Companies specializing in short-term houseboat rentals in Ontario number

approximately twenty and their operations extend widely from western Lake of the Woods to eastern Lake Ontario. Depending on size, a houseboat may provide sleeping accommodation for between 6 and 10 persons.

Boat use can vary widely, depending on size and amenities, from "day sailing" to extended cruising. Some owners even live-aboard during the entire boating season (May to October), although many public marinas and private yacht clubs prohibit seasonal live-aboards. Normal overnight accommodation on power cruisers or sailboats in the most popular size (8-9 metres long) varies between 3 to 6 persons and 3 to 5 persons respectively.

2.3 BOAT STATISTICS

2.3.1 Number of Boats

Licencing regulations require that any boat equipped with an engine of 7.5 kW (10 HP) or more must be federally registered, however registration records do not indicate if vessels are equipped with sleeping accommodations, kitchens, or toilets. Estimates of private and commercially owned pleasure boats in Ontario over 6 m in length which are likely to have overnight accommodations and/or associated amenities run as high as 40 000. Additionally, many power and sailing craft visit Ontario from the United States each year. It may be reasonable to assume that during the summer peak in July and August as many as 40 000 vessels will be in Ontario waters. Of this total, recent estimates put the number of private and rental houseboats in Ontario at over 600, most of which are operated on the inland waterways and lakes.

2.3.2 Densities

It is known that, in certain small quiet bays, concentrations of cruising boats (houseboats, power and sail) on a weekend during the summer can often exceed fifty vessels. Examples include Little Lake, Peterborough; Rotary Beach at Fenelon falls; Buckhorn Lake; Jones Falls; Chaffey Lock; Prinyers Cove; and so on. In many cases, boat densities in numerous Ontario harbours exceed fifty on a continual basis throughout the boating season.

It is probable that the greatest environmental impact of pleasure boating activities occurs in restricted waterways such as the Trent-Severn System, the Rideau System where boats may moor or anchor for days at a time, and in lake bays and harbours of refuge; as opposed to the open waters of the Great Lakes where boats are generally are on the move.

In order to establish the effects of grey water discharges from pleasure boats on receiving waters, it is proposed to select a representative quiet bay and estimate the contamination effects of grey water under conditions of high boat densities at high season.

2.3.3 Projections

A review of new pleasure boat licences issued in Ontario during the past ten years by Canadian Customs shows an annual increase of roughly 5000 per year. It is reported that sales of boats in 1985 were greater than for any previous year, and that sales at the Toronto International Boat Show in 1986 exceeded all other years. As well, one of the largest Ontario houseboat rental companies expects to add 40 or more units in 1986 in both the Rideau Canal and Lake of the Woods areas.

With improved production methods, reduced maintenance requirements due to modern construction materials, and the ability of owners to finance a high percentage (up to 80%) of the capital cost of new boats, a continued increase in the number of boats in Ontario waters can be expected for the foreseeable future.

2.4 BOAT PLUMBING SYSTEMS

2.4.1 General

A review was made of historical and advanced wastewater plumbing systems on pleasure craft, and also of potable water systems. Schematic drawings of typical systems for large and small pleasure craft - including houseboats, power cruisers, and sailboats - are shown in Figures 2.2 through 2.7. The main system variations among vessel types relate to the capacities of sewage (black water) holding tank and potable water storage tank, and the number of fixtures on an individual vessel - both of which increase with larger boat sizes having more sleeping accommodation.

Most houseboats are equipped with hot and cold water pressure systems including a shower unit, whereas these amenities are usually found only on larger (over 8.5 m) power cruisers and sailboats. On the latter types of craft, grey water from the galley and washbasin is typically discharged by gravity to the recreational waterway through a submerged hull outlet. Since the shower sump in these craft is often located below the waterline, an electric or manual pump with anti-siphon loop is provided to evacuate this grey water. On the other hand, that portion of houseboat grey water dumped overboard discharges via a drain pipe through the cabin floor between the pontoons to a point just above the waterline.

2.4.2 Sewage (Black Water) Handling Systems

A typical marine sewage (black water) system consists of a manually operated toilet discharging into an on-board holding tank for later removal at a shore-based pump-out facility. The holding tank capacity generally relates to boat size or extent of accommodation. Flushing water for the toilet is usually drawn directly from the recreational waterways through a hull fitting, although some houseboats use on-board fresh water for toilet flushing because of the difficulty of installing a through-hull fitting for raw water.

NOTES

1. POTABLE WATER CONSUMPTION MAY RANGE FROM 225 to 675 L/day·person.
2. SLEEPING ACCOMMODATION FOR UP TO TEN PERSONS.
3. ONE PUMP-OUT TYPICALLY PROVIDED FOR A 2-WEEK RENTAL OF HOUSEBOAT.
4. LARGER, OVER 12m LONG.
5. SINK WASTES TO SEWAGE HOLDING TANK ON SOME NEW HOUSEBOATS.

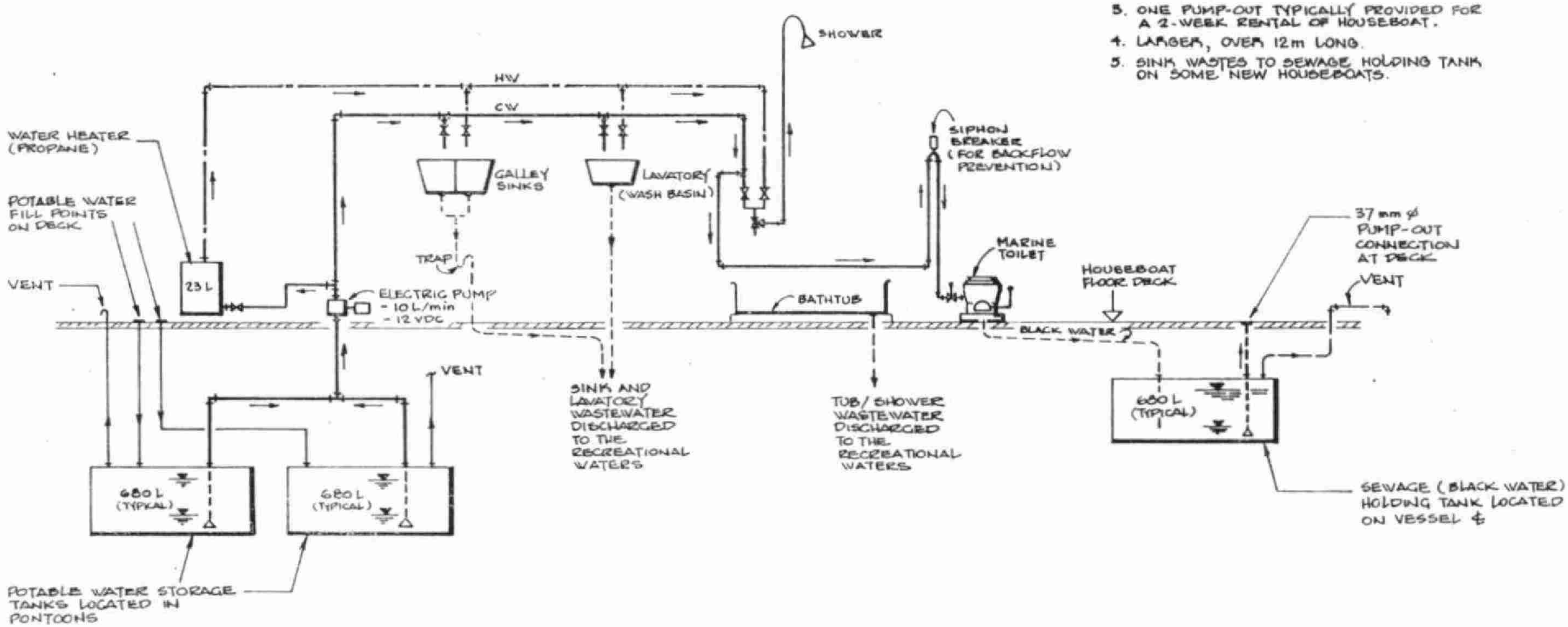

Figure 2.2 TYPICAL LARGER HOUSEBOAT PLUMBING SYSTEM

NOTES

1. OPTIONAL ROOF MOUNTED POTABLE WATER STORAGE TANK (66 L), WITH LAKE WATER USED FOR WASHING AND TOILET.
2. SOME VESSELS DO NOT HAVE TUB/SHOWER.
3. SLEEPING ACCOMMODATION FOR 6-8 PERSONS.

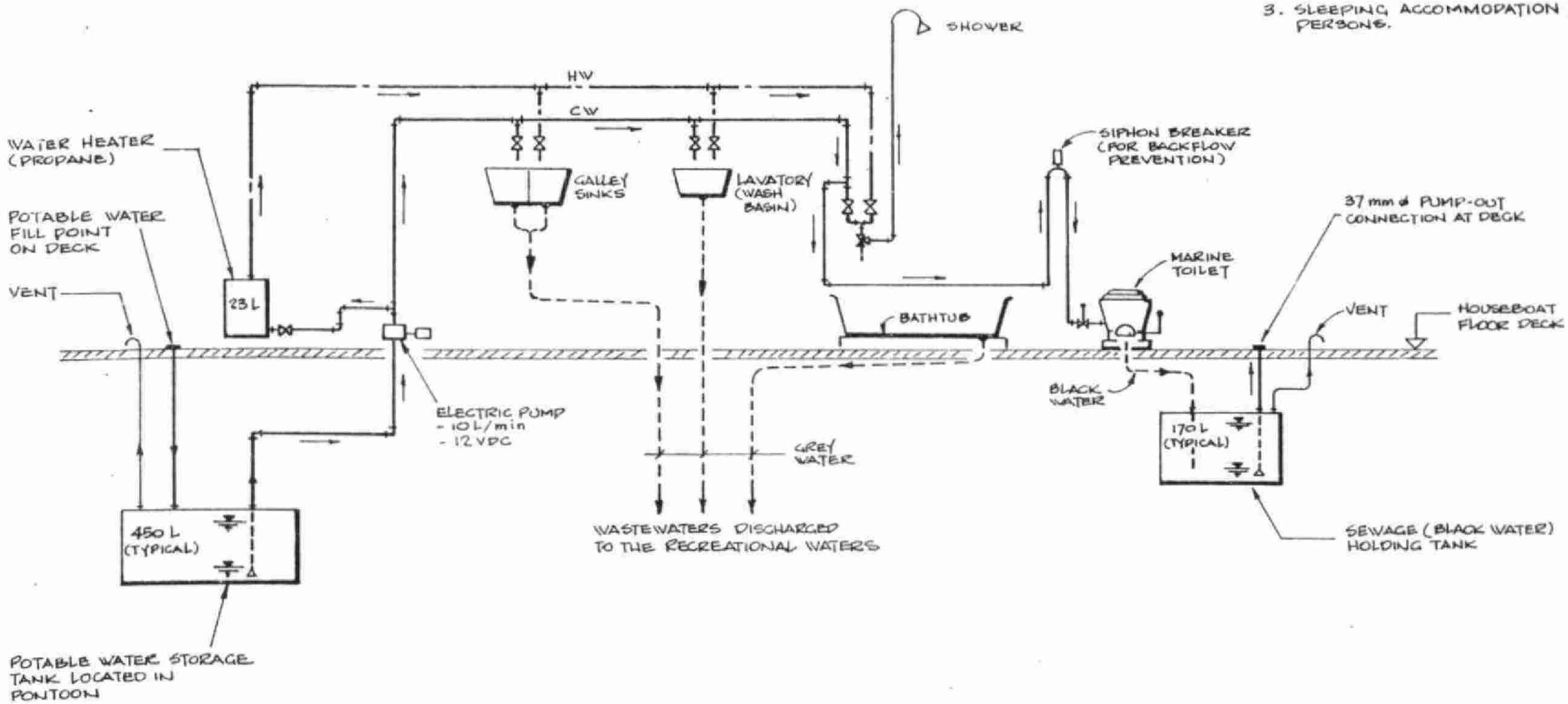

Figure 2.3 TYPICAL SMALLER HOUSEBOAT PLUMBING SYSTEM

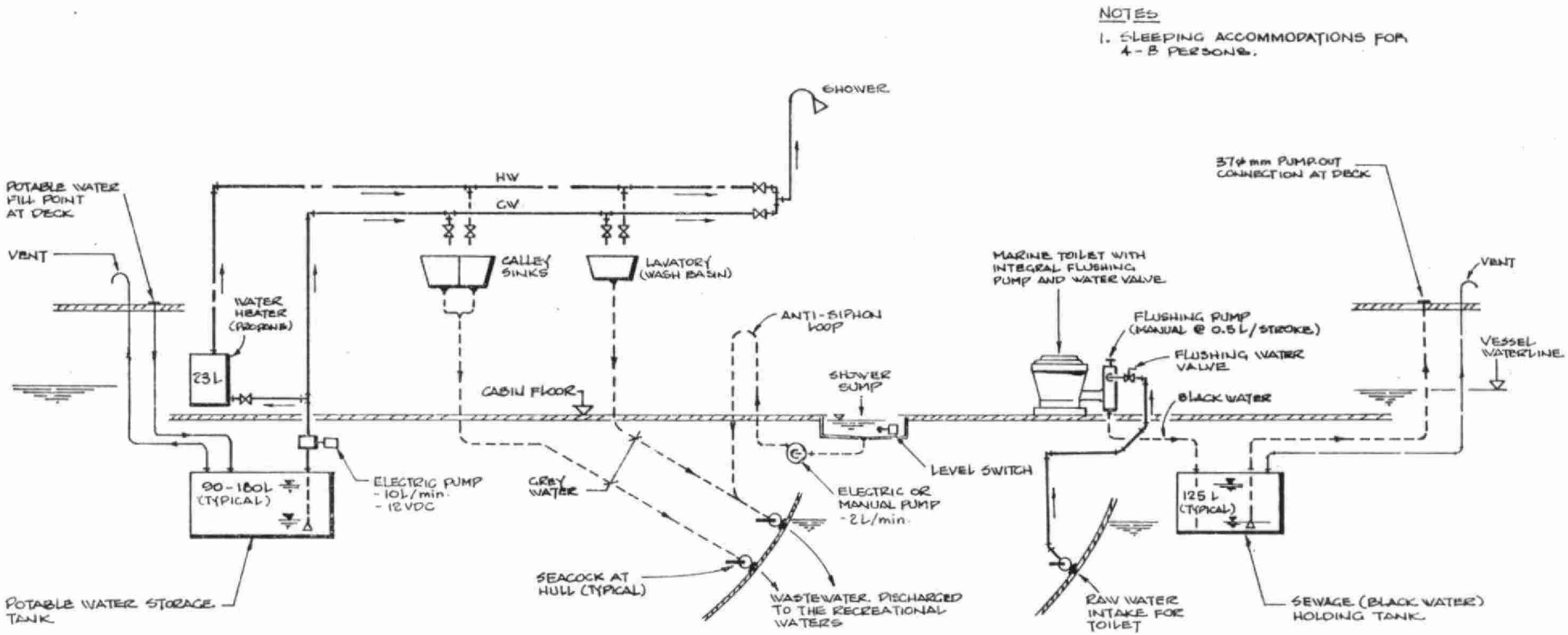

Figure 2.4 TYPICAL LARGER POWER CRUISER PLUMBING SYSTEM

NOTES

1. SMALLER: UP TO ROUGHLY 8.5 m LONG
2. SLEEPING ACCOMMODATION FOR 3-4 PERSONS.
3. BILGE PUMP FITTED (MANUAL OR ELECTRIC).

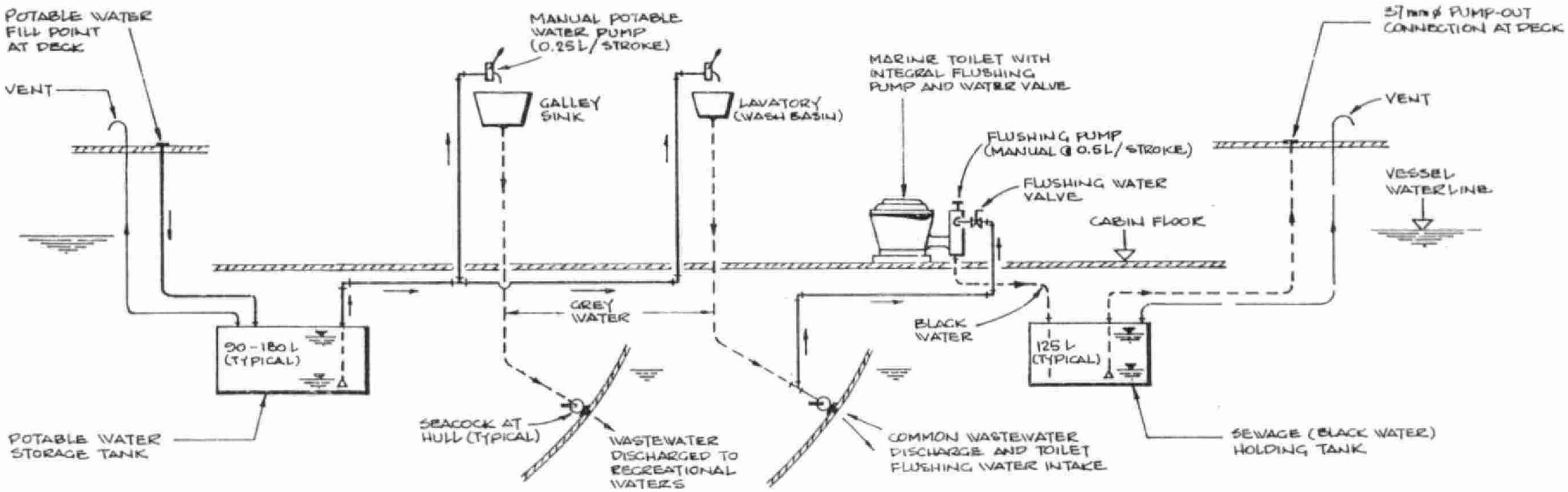

Figure 2.5 TYPICAL SMALLER POWER CRUISER PLUMBING SYSTEM

NOTES

1. SLEEPING ACCOMMODATIONS FOR 5 - 8 PERSONS.

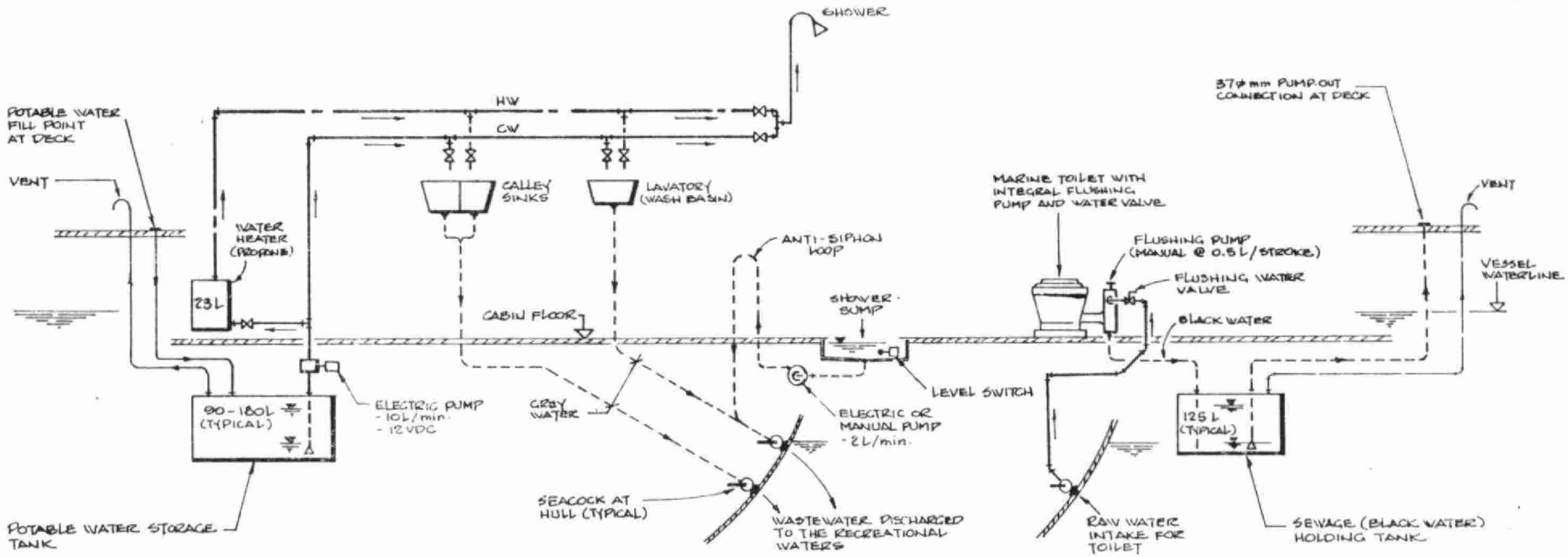

Figure 2.6 TYPICAL LARGER SAILBOAT PLUMBING SYSTEM

NOTES
1. SMALLER: UP TO ROUGHLY 8.5 m LONG.
2. SLEEPING ACCOMMODATION FOR 4 TO 6 PERSONS.
3. BILGE PUMP FITTED (MANUAL OR ELECTRIC).

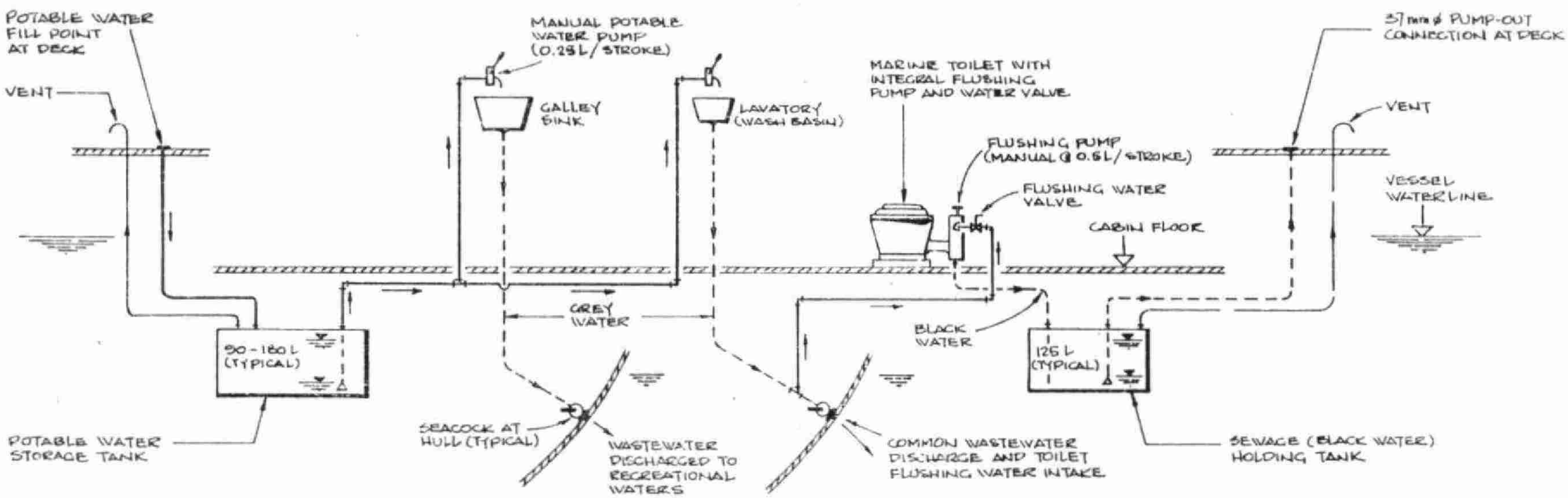

Figure 2.7 TYPICAL SMALLER SAILBOAT PLUMBING SYSTEM

Also available from specialty marine manufacturers are electric toilets; macerator pumping units; vacuum sewage systems (special toilet, vacuum tank, and vacuum pump); and treatment disinfection packages employing commercial hypochlorite as the bacteriacide. Alternatively, hypochlorite solution can be produced on-board by electrolyzing salt water. (When this system is used in fresh water, salt must be periodically added).

It is noted that, if wastewater treatment equipment were installed on a pleasure boat, current Ontario regulations would prohibit the discharge of treated effluent into receiving waters. A number of states in the U.S.A. have regulations similar to Ontario, but some states do permit treatment/disinfection devices as defined by U.S. Federal regulations.

2.4.3 Diverter Valve and Maverick Overboard Discharge Device

A sewage (black water) three-way diverter valve (commonly known as a 'Y' valve), as shown in Figure 2.8, may not, under Ontario regulations, be used to discharge sewage overboard. If fitted, the valve's direct overboard discharge branch must be effectively sealed, and an air space provided, to positively prevent sewage (black water) discharge while the boat is operating in Ontario waters. This restriction also applies in some other U.S. jurisdictions having designated "no-discharge" waters.

Three-way diverter valves are not customarily installed in new Canadian boats, however they are sometimes found in older boats, boats visiting from other provinces or countries, and used boats brought into Canada from foreign countries. Also, Ontario boat owners, intending to venture outside restricted waters or 'offshore', may retrofit 'Y' valves for use in those waters.

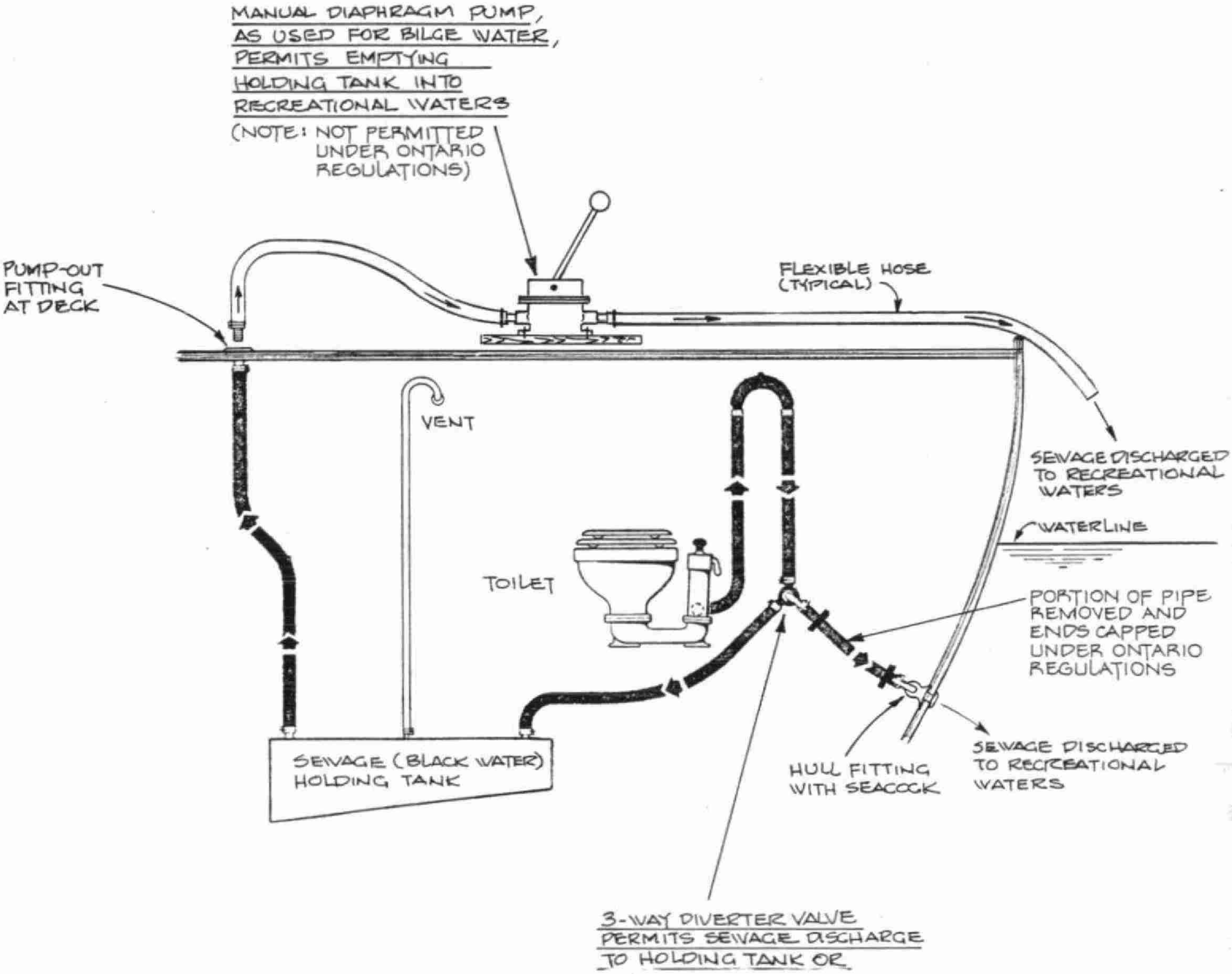

Figure 2.8 DIVERTER VALVE AND 'MAVERICK' OVERBOARD DISCHARGE DEVICE

Another variation is the 'maverick' deck pump-out assembly (Figure 2.8) consisting of a manual diaphragm-type bilge pump with a suction hose for connection to the boat deck pump-out fitting and an outlet hose for overboard discharge. This assembly is supposedly constructed for use offshore, and use of this type of device is not permitted in Ontario waters.

2.5 PUMP-OUT STATIONS

In 1985, public and private shore pump-out stations in Ontario were distributed generally as follows:

St. Lawrence River	29
Lake Ontario	64
Rideau Waterway/Ottawa River	24
Trent Severn Waterway	54
Muskoka	16
Lake Simcoe/Lake Couchiching	32
Lake Erie	18
Detroit River/Lake St. Clair	19
Georgian Bay/Lake Huron	55
Lake Nipissing	5
Lake Superior/Lake of the Woods/Rainy River	17
Other	42
TOTAL	375

Most of these pump-out stations are privately owned and operated facilities located at marinas, etc., and are available to all boaters. Approximately 10% of the total stations are situated at private yacht clubs for the use of their members and visiting vessels. Figure 2.9 shows the areas noted above and Appendix 'C' contains a complete pump-out station listing.

Typical pump-out charges range from $7.00 to $15.00/pump-out with the average cost being about $10.00/pump-out. Many boaters feel these rates are excessive. Reduced seasonal rates are sometimes available to boaters who rent a mooring/dock at a marina for the entire boating season. Private yacht clubs typically do not charge members or visiting boats for the use of pump-out facilities.

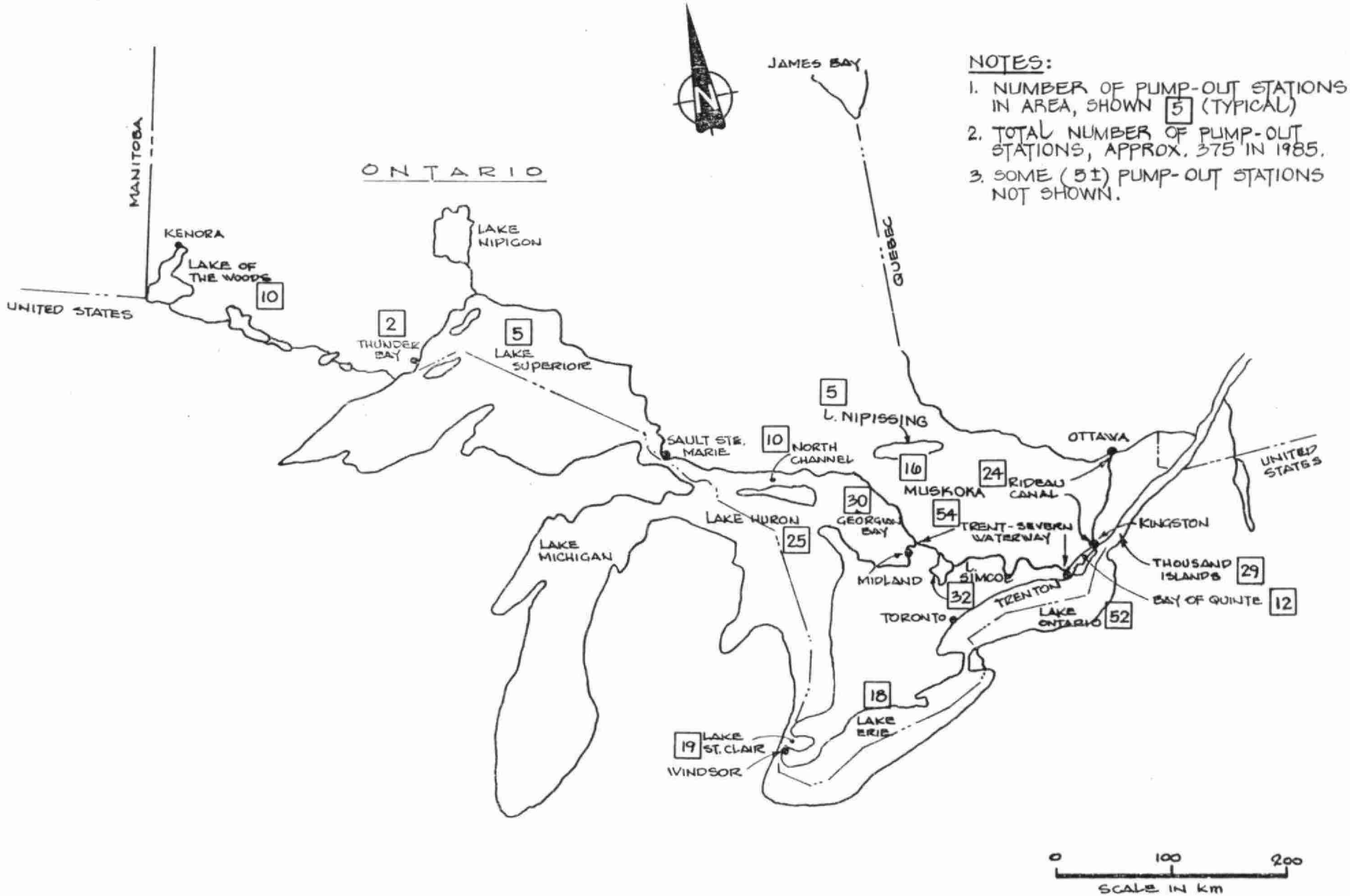

Figure 2.9 ONTARIO PLEASURE BOAT PUMP-OUT STATIONS

Disposal of pump-out station wastes may be by direct discharge into a municipal sewer system when available, or to a local holding tank for future removal by tank truck. Also, a septic tank system with tilebed may be utilized for final disposal of the wastes.

A drawing of a typical pump-out station and the basic requirements for ease of use are shown in Figure 2-10.

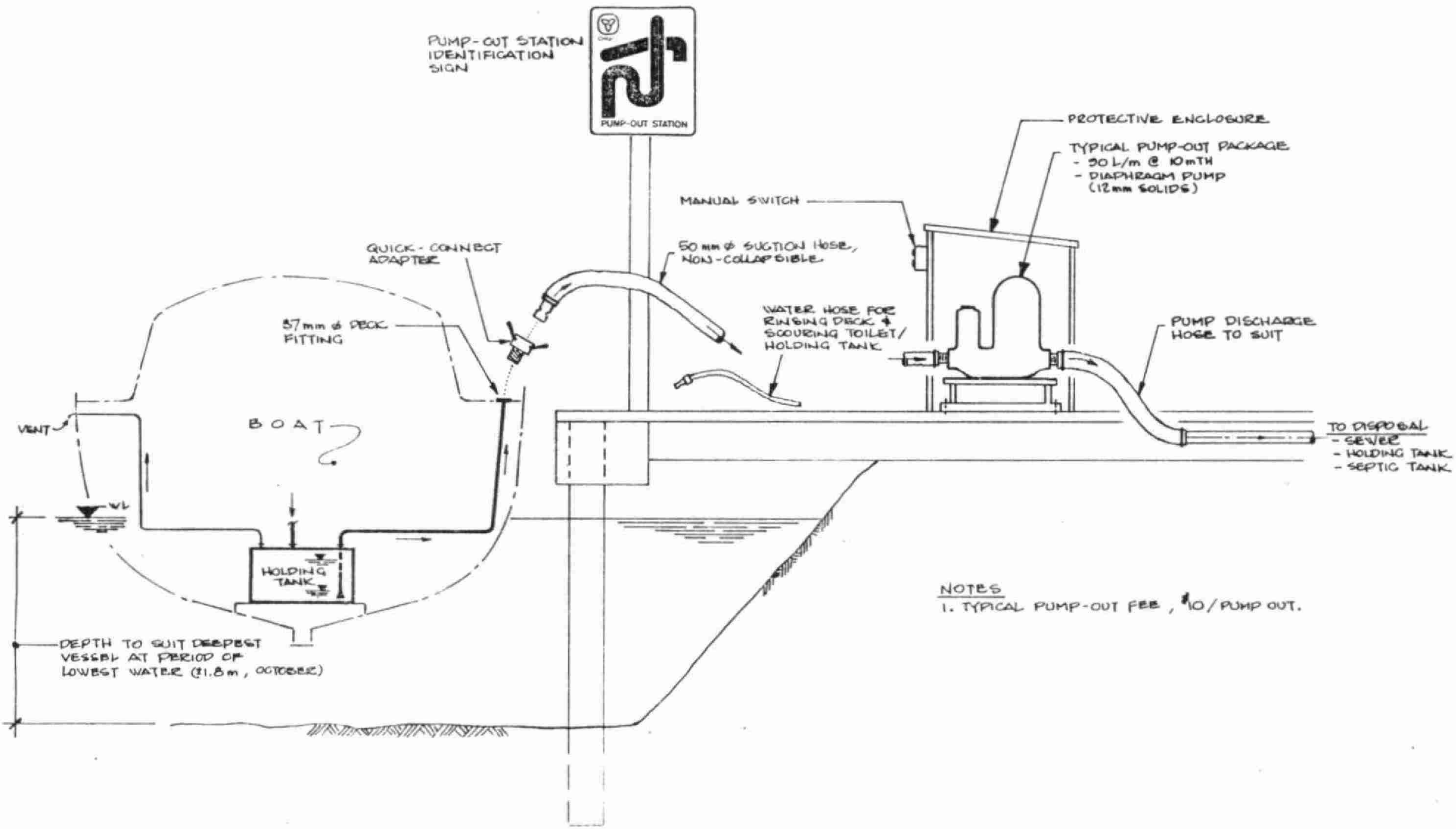

Figure 2-10 TYPICAL MARINA BOAT PUMP-OUT FACILITY

2.6 CURRENT REGULATIONS AND STANDARDS

2.6.1 Canadian Regulations for Discharge of Sewage from Pleasure Boats

In Ontario, discharge of sewage (black water) from pleasure boats and the requirement for boat pump-out facilities at marinas are regulated by the Ministry of the Environment's Environmental Protection Act, Regulation 305 and 310 respectively. These regulations are intended to prevent the overboard discharge of sewage (black water) and garbage, and to provide for the proper disposal of these wastes at land-based facilities.

Under Ontario Regulation 305, the following pleasure boat wastes may be discharged directly into recreational waters: liquid wastes, free of solids, from water used for household purposes - exhaust wastes, cooling water and bilge water. Sewage, defined as organic and inorganic wastes including human waste from toilets, solid waste, fuel and lubricants, is not permitted to be discharged into any water, but must be stored aboard for shore-based removal and disposal. Regulation 310, requires that marina operators provide facilities for disposal of solid wastes from pleasure boats, and provide or arrange for pump-out of boat holding tanks, and disposal of the sewage from the pump-out facility in accordance with applicable laws.

Boats operating in Ontario waters are subject to routine inspection by Ministry of the Environment staff. Ontario Provincial Police and RCMP officers are also empowered to inspect craft on behalf of the Ministry. Violators may be fined for non-compliance with the regulations.

Current Federal Government Regulations apply only to commercial vessels on the Great Lakes and the St. Lawrence, which may only discharge sewage into these water if treated by an approved marine sanitation device. Proposed Federal Regulations relating to sewage discharge from pleasure boats include a provision for allowing certain treatment systems (other than "macerator-

chlorinator" units) to be used, and are broadly similar to current Ontario regulations, but will only apply in a province (or areas of a province) when requested by the province concerned. There seems little chance of this happening in Ontario, particularly since it would, in any case, be by the Province.

Accordingly, continuation of the present provincially-operated scheme is considered to be preferable.

In Quebec, the discharge into the environment of liquid waste composed of organic or inorganic matter, even diluted with water, is prohibited under the Quebec Environment Quality Act. It is reported that this legislation includes provision for prohibiting the overboard discharge of sewage from pleasure boats.

2.6.2 United States Regulations

The United States Federal Environmental Protection Agency (EPA) regulates the discharge of sewage (black water) from all vessels into any waters within the EPA's jurisdiction. In addition, individual states certifying that particular state waters require greater environmental protection than the applicable Federal Standards provide can prohibit the discharge of any treated or untreated sewage after determination by the EPA that adequate land-based removal and disposal facilities are available. Presently, there are no Federal regulations controlling the discharge of grey water from pleasure boats, but there are some recently passed State ones which are noted hereafter.

All vessels with an installed toilet must be equipped with a U.S. Coast Guard certified marine sanitation device (MSD). Three types of MSD's are acceptable:

Type I Device - Flow-through type, effluent USCG certified to 1000 fecal coliform/100 ml, no visible floating solids.

Type II Device - Flow-through type; effluent USCG certified to 200 fecal coliform/100 ml, 150 mg/l total suspended solids.

Type III Device - No discharge type, USCG certified (i.e. holding tank).

A Y-valve may be installed to provide for direct discharge of sewage when the vessel is outside the three-mile limit, but the valve must be secured in the closed position when the vessel is within U.S. waters.

Enforcement of the EPA pollution prevention regulations is the responsibility of the U.S. Coast Guard which may issue a citation to violators.

Marine sewage (black water) discharge regulations presently in force in a number of States are summarized as follows:

New York*	- Type II and III MSD
	- Type III only on Lake George (i.e. no sewage discharge)
Minnesota*	- Type III MSD
Michigan*	- Type III MSD
Ohio*	- Type II and III MSD
Pennsylvania*	- Type I, II and III MSD
	- Type III in certain 'no discharge waters'
Illinois*	- Type III MSD
Indiana*	- Type II and III MSD
Wisconsin*	- Type III MSD
New Hampshire	- Type III MSD
New Jersey	- Type III MSD

* Direct access to Ontario waters.

2.6.3 Regulation of Grey Water Discharges

Generally, regulations presently in force in Canada and the United States do not prohibit the direct discharge of grey water to recreational waters from pleasure boats, however there are notable U.S. exceptions. For Lake George New York, recent regulations have been enacted prohibiting the discharge of all grey water from pleasure boats. Also, in the State of New Hampshire, grey water discharge into fresh water lakes and rivers has been prohibited since 1983, and additional regulations have been proposed to stop the use of chemical cleaners for washing boats, and to require that marinas provide suitable shore-based boat pump-out facilities and public toilets ashore for the use of boaters. In New Hampshire, compliance with the grey water discharge regulation is reported to be widespread, since marina operators are responsible for ensuring that boats comply with the regulation before they can be launched. Also, it is reported that proposed regulations in New York and Vermont would prohibit any wastewater discharges from boats into Lake Champlain, its tributaries and outlets.

2.6.4 Ontario Swimming Water Standards

Standards for waters use for swimming in Ontario are regulated through the Ontario Water Resources Act, Water Management Programs. These programs include, goals, policies and implementation procedures for managing the water resources of the Province. For waters used for swimming and bathing, aesthetics, pH, clarity and public health considerations are defined. In the latter category, fecal coliforms are one of the indicators of bacterial water quality and a potential health hazard exists if the fecal coliform count exceeds 100 counts per 100 ml. Where there is a risk of contracting a disease from the use of the water, public health considerations require confirmation that a hazard exists, notification of potential users, corrective action and surveillance of the water quality until the water can be declared safe for recreational use.

2.7 BOAT INSPECTION PROGRAMS

Boat and marina inspection programs to confirm conformance with marine sewage disposal regulations are carried out both in Ontario and the United States.

The inspection and enforcement program carried out in 1985 by the Ministry of the Environment involved eleven inspectors based at Peterborough, Welland, Windsor, Owen Sound, Parry Sound, Sault Ste. Marie, Kenora and Kingston. Results of this program are summarized as follows:

-	boats inspected	2450
	violations	171 (7%)
	convictions	4
-	marinas inspected	188
	violations	1
	convictions	0

Other programs conducted by MOE in 1983 and 1984 revealed that only 3 to 4 per cent of boats and marinas inspected were in violation of Ontario regulations.

Although the overall results of the 1985 program indicated that only 7% of the boats inspected were in violation of regulations, certain specific areas reflected problems i.e. the percentage of pleasure boats in violation of the sewage discharge regulations varied considerably (e.g.: Lake of the Woods = 14%).

3.0 REVIEW OF POLLUTION PROBLEM

3.1 HEALTH AND ENVIRONMENTAL EFFECTS

Effects on the environment and on the health of users of recreational waters from recreational boating may be real or perceived as real. When a swimming area is identified as "polluted" and dangerous to one's health, public concern increases; when the water surface is covered with patches of unsightly scum, the result is a perception of pollution whether or not bacterial or chemical contamination is present.

In the general view, the discharge of wastewaters, either black or grey, from boats may now be considered to violate the current "environmental ethic," and some residents and cottagers living on the more sensitive waterways have difficulty in reconciling the requirement for complete disposal of their household wastewaters versus the less stringent regulations imposed on marine wastewaters from recreational boats.

On the other hand, boaters may consider that their contribution to the pollution problems of Ontario waters is not significant when compared with discharges from other sources (commercial shipping, industrial facilities, community sewers, etc.).

Notwithstanding the foregoing, there is little up-to-date information on the characteristics and amount of grey water generated and discharged by pleasure craft in Ontario, or the impact of these discharges on the quality of the receiving waters.

In order to assess the effect of grey water from pleasure boats on receiving waters, the extent and quality of the discharges from the boats and the quality of receiving waters, must be established and analysed.

3.2 PUBLIC CONCERNS

The concerns of various public groups regarding the impact of pleasure boating varies widely depending on a multitude of subjective factors such as whether one is a boater or cottager or environmentalist, etc. (and in what combination).

Cottage owners are required to dispose of grey water by means of a septic system or similar land disposal scheme. Many hold the view that permitting the direct discharge of grey water from pleasure boats is legally inconsistent, and also represents a violation of the "environmental" ethic. On the other hand, many boaters argue that they are being singled out as polluters when the impact of boat grey water on receiving waters is perceived to be miniscule in comparison to pollution from commercial shipping, industrial, and municipal sources.

Added to this are the concerns of boat rental companies and other commercial facilities providing support services to boaters who see increased regulation of boating activities as having a potentially negative affect on their operations because of higher costs. An exception would be pump-out operators who would enjoy increased business.

Finally, it is probable that, phsychologically, many local cottagers and residents along Ontario's waterways see the increase of boats in their areas as an encroachment on their waterfront territory. Certainly, inconsiderate behaviour by boaters - such as excessive noise, ribald behaviour and partying may trigger related complaints.

3.3 SOURCES AND DISPOSAL OF GREY WATER

Pleasure boat grey water is generated from various housekeeping (boat keeping) and hygenic activities. On a boat suitable for extended overnight accommodation, grey water will be produced during cooking and galley clean-

up, and from using the boat wash-basin (and shower where installed). Variations are as shown previously in Figures 2.2 to 2.7.

Grey water from these fixtures is typically discharged overboard via a simple gravity piping arrangement with submerged outlet for crafts with hulls or free discharge for most houseboats with pontoons. In contrast to drain piping found in homes or cottages, boat fixture drains are of smaller diameter (13 - 25 mm) and are not usually fitted with traps. Shower wastewater on power cruisers and sailboats is collected in a sump which is below the boat waterline and therefore fitted with a small electric or manual pump and piping loop to permit overboard disposal.

3.4 BACTERIAL CONTAMINATION OF LAKES AND RIVERS DUE TO HUMAN ACTIVITY

3.4.1 General

Contamination of lake and river waters used for drinking and recreational activities by human excrement or other sewage is the greatest danger associated with the health and wellbeing of the population utilizing the waters. If among the contributors to water contamination are cases or carriers of infectious diseases, the water may contain the living micro-organisms which cause these diseases, and the use of such water for drinking or swimming may result in fresh cases. Sewage-polluted water may also contain the viruses of poliomyelitis, other viruses of the enterovirus group, or the virus of infectious hepatitis.

Animals and birds, particularly seagulls, also carry intestinal organisms pathogenic to man. The use of contaminated water for drinking and in the preparation of food may allow the multiplication of intestinal pathogens, and a risk of infection.

Pathogens present in water are usually greatly out-numbered by the normal intestinal organisms, and tend to die out more rapidly[1]. The direct search for the presence of specific pathogenic bacteria or viruses in water is impractical and time-consuming, therefore bacteriologists have evolved a simple and rapid test for the detection of normal intestinal organisms such as coliform bacteria or Fecal Streptococci. The total coliform organisms density is a quantitive indicator of the presence of pollution of the coliform group of organisms and a qualitative indication of the probability of the presence of pathogens.

The organisms most commonly used as indicators of fecal pollution are the coliform group as a whole, and particularly Escherichia coli which is undoubtedly of fecal origin. Since coliform bacteria are present in large numbers in feces and sewage, and can be detected in numbers as small as one

in 100 ml of water[1], they are the most sensitive indicators at our disposal for demonstrating the fecal contamination of water. E. coli is the most frequent type of coliform organism present in the human and animal intestine, being found in numbers up to 10^9 per gram of fresh feces. Apart from excretal contamination it can also be found in soil, vegetation or water.

The presence of E. coli in a water sample indicates pollution of either human or animal origin. Since there is no satisfactory method for determining whether E. coli is of human or animal origin, its presence should always be regarded as indicating potentially dangerous pollution. There is evidence that the feces of birds, rodents and domestic animals may contain organisms of the salmonella group including Salmonella paratyphi B. It is noted, that the MOE "Blue Book" contains a method of ratios on page 43 which requires the use of fecal strep data in addition to fecal coliform, however this is not critical for this study.

Coliform organisms other than E. coli can also be found in water sources as a result of contamination by soil washings or from growth on decaying vegetation, especially during the warm, summer weather.

Some part of the bacterial contamination of lakes and rivers comes from the extensive use of waterways by commercial and recreational craft during the summer months. Waste discharges from watercraft include some sanitary wastes. They may contain concentrations of pathogenic organisms that cause such diseases as dysentery, typhoid or paratyphoid fevers, gastroenteritis and infectious hepatitis - endangering the health of those using the receiving waters[1]. Viral diseases can also be transmitted by water and can reach public water supplies from the discharges of pleasure and commercial watercraft, from the effluent of municipal sewage treatment plants, and from urban and rural runoff. Although viruses require the presence of living susceptible cells to grow and multiply, current evidence indicates that they survive outside these cells for considerable periods of time[1]. Apparently, viral survival is longest in slightly or moderately polluted waters, such as the pollution conditions in many areas of both Lake Erie and Lake Ontario.

Coliform bacteria, the indicators used as an index of bacterial pollution, do not serve as indicators for viral pollution. There is as yet no suitable agent available which can be used as an indicator of the presence of viruses.

The literature information on the relation between open water contamination and incidence of illness is very limited.

3.4.2 Related Investigations

Confined Waters

A two-year study was completed in 1960 by Udell[2] towards assessing general and bacterial pollution trends in certain marine waters resulting from waste discharged from boating activities. The author observed that, in harbours exhibiting significant replacement of water through tidal flushing, an increase in pollution levels attributable to boating activity could not be detected. The degree of bacterial and other pollution contributed to waters of marinas or confined embayments (not exhibiting complete or near-complete flushing) by boating activity was found to be directly proportional to numbers of boats anchored or docked in the areas. Udell stated that bacterial densities did not remain at levels sufficient to violate classification standards for bathing or shellfishing waters.

Bathing

As far as bathing is concerned, Udell presented the bacterial pollution requirements of the health department of Nassau and Suffolk Counties, New York as not exceeding 240 coliform organisms per 100 ml of sample expressed as a Most Probable Number (MPN). The Canadian Water Quality Guidelines for direct contact recreation[3] (swimming, bathing, wading, water skiing) put the maximum limit for total coliform organisms at 500/100 ml (MPN), and for fecal coliform organisms at 200/100 ml (MPN). The Ontario standard for fecal coliform is 100/100 ml.

Fishing

For shellfishing, an example of the fishing scenario, Udell recommended that "only shellfish growing in water free from sewage type pollution should be taken for food." Tables estimating the allowable number of boats in shellfish areas, applicable also to water areas for direct contact recreation, have been developed by Furfari[4]. The author made some basic provisions: (a) the boats are the only source of contamination with coliform organisms, (b) a population equivalent value of 1.25 for a small boat was assumed, and (c) a theoretical total coliform contribution per person-day of 80×10^9 was used in the calculations. Table 3-1, after Furfari, enables the calculation of the number of boats for a known area and known depth of water to maintain the water quality required for shellfish growing and for recreational activity. In another study on the effects of boating activity on concentration of fecal coliform organisms in a shallow estuarine area of Rhode River, Faust[5] observed that the concentration of fecal coliforms increased from 3 to 28/100 ml soon after the arrival of boats, persisted during their stay, and decreased soon after the boats departed the area. The author concluded that fecal coliform concentrations were positively correlated with the number of boats. Faust also determined that 2.2×10^5 m^3 of water was needed per boat with four occupants to maintain the fecal coliform levels below 14/100 ml. It is worthwhile to mention that Canadian Guidelines[3] indicate higher than 14/100 ml limits for fecal coliform organism concentrations in water-namely 23/100 ml for shellfish growth, and as high as 200/100 ml for direct-contact recreation activity.

The pollution from waste discharged into estuaries and embayments from small boats depends upon: (a) quantities of waste discharged per unit area, (b) dilution available, (c) circulation of waters, and (d) survival rates of pathogenic organisms in the specific receiving water.

TABLE 3-1

ALLOWABLE NUMBER OF BOATS IN SHELLFISH AREAS (AFTER FURFARI[4])

(No Background Coliform)

Area sq. miles (km^2)*	Depth ft. (m)*	Number of Boats	Area sq. miles (km^2)*	Depth ft. (m)*	Number of Boats
0.1 (0.26)	5 (1.5)	3	0.5 (1.3)	5 (1.5)	14
	10 (3.0)	6		10 (3.0)	28
	15 (4.5)	9		15 (4.5)	42
	20 (6.0)	12		20 (6.0)	56
	25 (7.5)	14		25 (7.5)	70
	30 (9.0)	17		30 (9.0)	84
	40 (12.0)	23		40 (12.0)	112
0.25 (0.65)	5 (1.5)	7	1.0 (2.6)	5 (1.5)	28
	10 (3.0)	14		10 (3.0)	56
	15 (4.5)	21		15 (4.5)	84
	20 (6.0)	28		20 (6.0)	112
	25 (7.5)	36		25 (7.5)	140
	30 (9.0)	42		30 (9.0)	184
	40 (12.0)	56		40 (12.0)	224

* Conversion to metric - approximate

In a more recent paper about swimming-associated health risk, Seyfried et al.[6] reported that, during the summer of 1980, both swimmers and non-swimmers were enlisted in a prospective epidemiological study to determine the relationship between swimming, water quality, and the incidence of illness. Results of 4537 interviews showed that crude morbidity rates were 69.6 per 1000 swimmers versus 29.5 per 1000 non-swimmers. Swimmers experienced respiratory ailments most frequently followed by gastrointestinal illness, eye, ear, skin, and allergenic symptoms respectively.

Sludge Dumping

The effect of the dilution of sewage sludges disposed into the ocean on the potential microbial hazard to human health was discussed by Davis et al.[7]. As was shown earlier by Brandes[8], the concentrations of total and fecal coliform organisms in sewage sludge from a household are in some cases as high as 9.9×10^7 and 7.8×10^6 per 100 ml respectively. The authors[7] made an in-depth assessment of the danger to human health due to disposal of the sewage sludge in New York bight. They came to a conclusion that, due to rapid initial and subsequent dilution of the sludges, as well as sedimentation and microbial die-off, the ocean water met the New York water quality standards for marine recreational waters.

Coliform Extremes

An extreme case of lake pollution was presented by Gupta[9]. The author discussed certain microbiological, biological, and chemical aspects of a highly polluted lake in India which was characterized by heavy input of domestic sewage and other organic pollutants. The most probable number (MPN) for total coliform bacteria in the lake water varied from 0.59×10^5 to 3.61×10^5 per 100 ml which was much in excess of the Canadian permissible total coliform organisms (MPN) concentration in water for direct contact recreation.

Pathogen Survival

An interesting view about survival of pathogens in seawater was expressed by Brayton et al.[10]. It had previously been accepted that pathogens do not survive in the marine environment and therefore do not pose a threat to human health. This concept was based on empirical observations that pathogenic micro-organisms and indicator organisms like E. coli "die off" in seawater i.e., they cannot grow on culture media. However, laboratory data collected by Brayton et al. showed that human pathogens in seawater become "non-culturable" but these non-culturable cells remain viable. In some cases they are fully capable of producing pathological changes when introduced into test animals. Such results have been obtained with Vibrio cholerae, Enterotoxigenic E. coli, Salmonella enteritidis and Shigella species. Conclusions drawn indicate that culture techniques alone will not suffice to ensure the safety of coastal waters, and especially shellfish contaminated in those waters.

The survival of Vibrio cholerae and Escherichia coli in estuarine waters has been studied by Hood[11]. In in-vitro estuarine water the survival of V. cholerae and E. coli was determined by plate counting and direct counting techniques. Viable cells of E. coli decreased rapidly in both sterile and non-sterile estuarine waters. Direct counts revealed that E. coli cells were intact in the estuarine water, but attempts to resuscitate them were unsuccessful. The data suggest that V. cholerae survives better in estuarine water than E. coli.

According to Dubos[12], the survival of Vibrio cholerae outside the host is favoured by dampness and low temperatures but in any case it is not of long duration. The V. cholerae remained viable in river water up to 17 days, and in seawater as long as 4 days. They have been recovered from septic tank effluent up to 5 days, and from a few hours to 2 weeks after experimental contamination of food. These periods are long enough to allow transfer of infection.

Table 3-2 shows the survival time of some types of fecal organisms in different environments.

3.4.3 Discussion of Bacterial Results Obtained from Grey and Black Water Investigations

A comparison of bacterial characteristics of the grey water and black water from four investigations is presented in Table 3-3. The amount of information on grey water bacterial and chemical characteristics is limited. The first and basic source of knowledge of this matter comes from a comprehensive report by the National Swedish Institute for Building Research Nr 24/68 of 1968[14]. There are also Canadian reports prepared by the Ontario Research Foundation[15/16] and by the Ontario Ministry of the Environment[17].

Before comparing the concentrations of coliform organisms in grey and black waters it is of interest to review the different methods and techniques applied by the respective investigators.

Swedish Insititute (Olsson)

According to Olsson et al.[14] of the Swedish Institute, their interest in studying the grey water characteristics arose from the observed surprising phenomenon that normal household wastewater (black plus grey) contains more fecal coliform bacteria than apparent from the count of coliform bacteria in fresh feces generated by the occupants of the house. This showed that the wastewater contains a great many fecal bacteria which must have originated from sources other than feces in black water. They started an investigation to gather information concerning the distribution of some of the ordinary groups of micro-organisms present in different categories of household wastewater. The authors stated clearly that "no similar investigations of wastewater from households have been carried out previously"[14] indicating that little previous work had been done in this particular area, i.e. pollution from grey water.

TABLE 3-2

SURVIVAL TIME OF SOME TYPES OF
FECAL ORGANISMS IN DIFFERENT ENVIRONMENTS

Nr	Bacteria	Environment	Survival Time	Source
1	Escherichia coli	In feces at 0°C	About 1 year	13
2	Escherichia coli	In water at 55°C	1 hour	13
3	Escherichia coli	In water at 60°C	15 minutes	13
4	Some strains of E. coli	In water at 60°C	1.5 hours	13
5	Some strains of E. coli	In water, dust, sand and on the surface of matter	Weeks or even months	13
6	Shigella flexneri Shigella sonnei	In water at 19 - 24°C	3 - 9 days	13
7	Typhoid bacteria	In sea water	35 days	2
8	Vibrio cholerae	In river water In sea water In septic tank effluent	Up to 16 or 17 days Up to 4 days Up to 5 days	12

TABLE 3-3

CONCENTRATIONS OF COLIFORM ORGANISMS IN GREY AND BLACK WASTEWATER

Bacteria Group	Units	GREY WATER			BLACK WATER	
		Olsson et al Ref. (14)	Brandes Ref. (17)	Smith et al Ref. (16)	Olsson et al Ref. (14)	Brandes Ref. (17)
		Kitchen & Bathroom* Combined (Household)	Kitchen & Bathroom* Combined (Household)	Galley & Shower Combined** (Cargo Vessel)	Vacuum Toilet	Black Water Septic Tank
Total Coliform Organisms	counts per 100 ml	3.8×10^6	117×10^6	550×10^6	56.2×10^6	2.6×10^6
	counts per person per day	4.1×10^9	30.2×10^9	63.3×10^9	4.8×10^9	4.6×10^9
Fecal Coliform Organisms	counts per 100 ml	0.9×10^6	13.0×10^6	109×10^6	45×10^6	1.4×10^6
	counts per person per day	1.0×10^9	1.8×10^9	12.6×10^9	3.8×10^9	2.0×10^9

* Toilet wastewater not included.

** Average concentrations have been calculated from results shown in Smith's report.

The location of the Olsson et al. investigation was a building containing 25 apartments which the owners and Stockholm City Real Estate Department had put at the disposal of the Institute for Building Research. A Liljendahl vacuum flushing system was installed in the building, with separate drainage stacks splitting up household wastewater into its principal components: black water from vacuum toilets; and grey water from kitchens, bathrooms, and laundries. Due to the manner in which the pipes were installed in the building, it was possible to obtain wastewater samples from the kitchen alone, from the bathroom alone, from a combination group consisting of the kitchen and bathroom, and from the laundry. The investigators collected samples directly from the pipes and analysed them at once. The same standard methods of testing in the laboratory, as used in Canada and the U.S.A., were applied (Table 3.3).

Ontario Research Foundation (Pancuska & Smith)

Two grey water bacteriological studies have been carried out on a Great Lakes cargo carrier - S.S. John A. France, 75 foot in beam by 723 feet long, and manned by crew of 30. One study was done by Pancuska et al.[15] of ORF in 1975, and the other by Smith et al.[16] of ORF on the same carrier in 1977. Samples from the collection plumbing lines from the galley and showers were taken regularly and tested for total and fecal coliform organisms.

Ontario Ministry of the Environment (Brandes)

One grey water study was carried out by Brandes[17] of Ontario MOE in 1978. A three-resident, single-family household located in Hawkestone, Ontario, was selected for the study because it already had two separate wastewater treatment and disposal systems - one for grey and one for black wastewater. Both had been used for some time by the household. Grey water samples were taken: a) from the grey water septic tank, b) from a pipe directly beneath the kitchen sink and c) from a pipe connecting the kitchen sink and the

bathroom with the grey water septic tank. The samples were tested in an MOE laboratory the same day they were collected from the pipes. Black water samples were also taken from the black water septic tank.

Concentration of Total Coliform Organisms

The average concentration of total coliform organisms in the grey water from the kitchen and bathroom combined in the Olsson et al. study[14] was 3.8 X 10^6/100 ml i.e., almost the same concentration as in the black water septic tank shown by Brandes (2.6 X 10^6/100 ml) but about 16 times lower than the concentration of total coliform organisms in the black water from a vacuum toilet which uses relatively low amounts of water for flushing. An average of 8.5 L/person-day in Olsson's vacuum toilet as compared to 65.3 L/person-day in a normal household toilet (Table 3.4).

Very high concentrations of total coliform organisms were also found in effluents from kitchens and bathroom combined, by Brandes (117 X 10^6/100 ml) and by Smith (550 X 10^6/100 ml).

The number of total coliform organisms from the kitchen and bathroom combined in Brandes' study was 30.2 X 10^9 per person per day and in the Olsson et al. study: 4.1 X 10^9 (Table 3-3), i.e. about 6 times higher than and almost equal to (respectively) the average concentration (4.7 X 10^9) in black water from both studies.

TABLE 3-4

HOUSEHOLD GREY AND BLACK WATER USAGE
(IN LITRES PER PERSON PER DAY)

Source	Winneberger Ref. (18)		Laak Ref. (19)		Bennett et al. Ref. (20)		Siegrist et al. Ref. (21)		Average Cols. 1 - 4		Olsson et al.[1] Ref. (14)		Pancuska[2] et al. Ref. (15)	
	1/p.d.	%	1/p.d.	%	1/p.d.	%	1/p.d.	%	1/p.d.	%	1/p.d.	%	1/p.d.	%
	Col. 1		2		3		4		5		6		7	
Kitchen	25.6	10.6	13.6	8.7	26.5	15.6	18.6	11.5	21.1	11.6	51.0	39.2	Galley 54.6	28.6
Bathroom	75.7	31.4	40.1	25.6	41.6	24.4	37.9	23.5	48.8	26.7	62.0	47.8	68.2	35.7
Laundry	33.1	13.7	28.0	17.9	45.4	26.6	39.8	24.6	36.6	20.1	8.5	6.5	-	-
Toilet (Black Water)	94.6	39.2	74.9	47.8	56.8	33.4	34.8	21.6	65.3	35.8	8.5	6.5	68.2	35.7
Other[3]	12.3	5.1	-	-	-	-	30.3	18.8	10.6	5.8	-	-	-	-
T O T A L	241.3	100	156.6	100	170.3	100	161.4	100	182.4	100	130.0	100	191.0	100

[1] Liliendahl vacuum drainage system was used by Olsson et al.

[2] Water usage on a Great Lakes bulk cargo carrier was presented by Pancuska et al.[15].

[3] Drinking, cleaning, sprinkling, car wash, etc.

Concentration of Fecal Coliform Organisms

Of greater interest is the comparison of concentrations of fecal coliform organisms in effluent from kitchen and bathroom with concentrations in black water.

Again very high concentrations of fecal coliform organisms were found in the effluents from the combined galley and shower by Smith et al. (109 X 10^6/100 ml), and from the kitchens and bathrooms combined by Brandes (13 X 10^6/100 ml) and by Olsson et al. (0.9 X 10^6/100 ml). Refer to Table 3.3.

Fecal coliform organisms, expressed in numbers per person per day, (a better indicator than numbers per 100 ml), are in the effluent from the combined kitchen and bathroom: Olsson et al., 1.0 X 10^9/person.day in grey water versus 3.8 X 10^9/person.day in black water, and Brandes 1.8 X 10^9/person.day in grey water versus 2.0 X 10^9/person.day in black water (Table 3.3). These data are in good agreement.

Concentrations of fecal coliform organisms in the effluent from the galley and shower calculated from Smith et al. were 109 X 10^6/100 ml and 12.6 X 10^9/person.day. The latter was much higher than in the black water of the two other reports.

As it follows from Table 3-5 presenting Olsson's results, the concentration of total coliform organisms in the effluents from the grey (kitchen) water is about 2.5 times higher than in the black (toilet) water. However, because of the large variability of coliform data, it is conventional to compare data on an "order of magnitude" basis. Accordingly, the concentrations are on the same order of magnitude.

TABLE 3-5

NUMBER OF COLIFORM ORGANISMS
FOR DIFFERENT CATEGORIES OF WASTEWATER
(after Olssón et al[14])

Bacteria Group	Col. 1 Kitchens	2 Bathrooms	3 Total Kitchens & Bathrooms	4 Combination of Kitchens & Bathrooms	5 Average of Cols. 3 & 4	6 Black Water	7 Total Cols. 5 & 6
Total Coliform Organisms (x 10^9/person.day)	11.86	0.96	12.82	4.12	8.47	4.78	13.25
Fecal Coliform Organisms (x 10^9/person.day)	2.26	0.16	2.42	1.00	1.71	3.83	5.54

Discussion on High Bacterial Contamination from Grey Water

No clear explanation of the reasons for observed high concentrations of coliform organisms in kitchens and galleys was given by the investigators. Olsson et al.[14] were surprised when finding for the first time in that kind of test, relatively high counts of fecal coliforms in effluent from kitchens. Olsson et al. supposed that: "temporary concentrations of bacteria in kitchen grey water may be connected with emptying of buckets of dirty water after cleaning, or water after washing baby clothes. The humid atmosphere in the kitchen and the ample supply of nutrition there (food-stuffs of biological origin) creates a favourable atmosphere for growth of bacteria".

Pancuska et al.[15] suspected that an incubation and growth of fecal and total coliform bacteria can take place in the pipes through which the wastewater from the galley, shower and laundry is passing. They suspected also that high coliform counts "could arise from the use of unchlorinated lake or river utility water used for showers and laundry." Pancuska stressed that the pollution regulations for shipping on the Great Lakes, do not require treatment of galley and shower wastes before discharging. He suggested reconsideration of existing regulations (1975).

Smith et al.[16] carried out an extensive grey water study on the same bulk cargo carrier, studied by Pancuska et al. and used for transporting grain. Tests of the utility water for coliform presence, recommended previously by Pancuska, did not show any fecal coliform organisms. The authors supposed that: "grain dust contaminated with rodent feces might be a potential source of great numbers of coliform organisms in the galley and shower wastewater".

The very high concentrations of total and fecal coliform organisms in the grey water from the kitchen and bathroom combined, observed by Brandes, were confirmed in the findings presented in the other reports. In Brandes'

study, samples were also taken directly from the drain pipe beneath the kitchen sink, and from the drain pipe carrying the combined effluent from the kitchen and the bathroom. The samples were tested in the MOE bacteriological laboratory on the same day. The average quantities of total coliform organisms in the effluent from the kitchen and bathroom combined appeared to be 45 times higher than in normal septic tank effluent. The quantities of fecal coliform organisms were about 9 times higher.

It seems that the quantities of contaminants in the effluent from the drain pipes or from the septic tanks do not represent the direct contribution of contaminants by residents of a house or a boat. Some of the contaminants, particularly the micro-organisms, are subjected to biological transformation during the time they are detained in the drain pipe or in the septic tank. A sample of effluent taken from the drain pipe beneath the kitchen sink was tested in the MOE laboratory for 12 days (288 hrs) to observe the effect of time on total and fecal coliform concentrations (Figure 3.1).

After 2 hours, concentrations of 7.5×10^6/100 ml of total coliform organisms and 0.53×10^6/100 ml of fecal coliform organisms were observed. The sample was kept in the laboratory at a temperature of 20°C and tested every 2 to 4 days for concentrations of coliform organisms. A maximum concentration of total coliform organisms was observed during the time interval between 24 to 96 hours after the sample was taken. The maximum concentrations reached were 119×10^6/100 ml of total and 5.1×10^6/100 ml of fecal coliform organisms. After that period a drop in concentrations of the coliform organisms was observed. The ability of the coliform organisms to grow abundantly in the sampling bottles at a temperature of 20°C suggested that a similar growth could also take place inside the drain pipes. The temperature inside the pipe beneath the kitchen is often higher than 20°C and the bacterial growth can go on even faster.

The results of the taxonomic identification of the bacteria from the sample taken from beneath the kitchen sink showed that all the fecal coliform

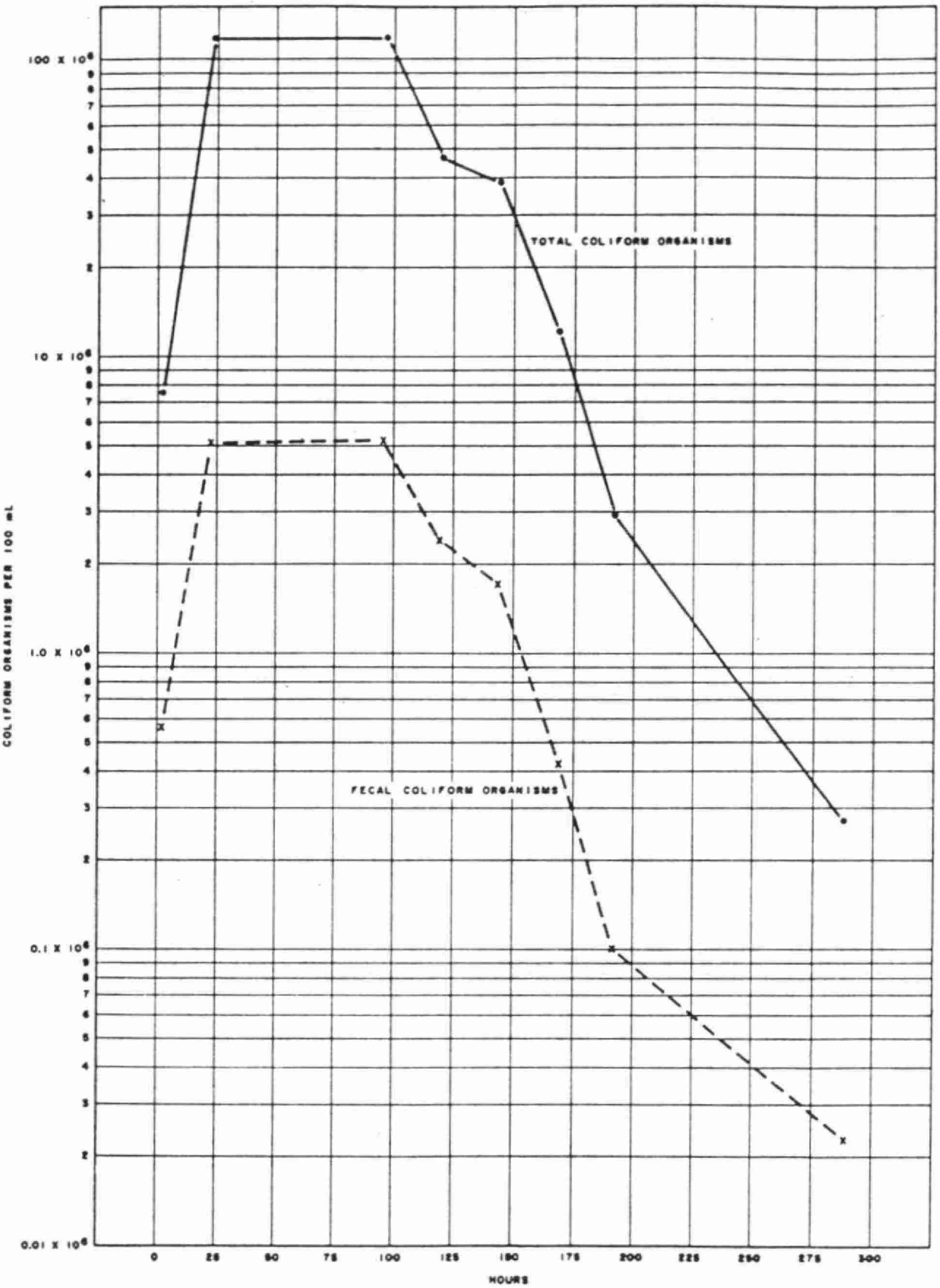

Figure 3.1 MULTIPLICATION RATE OF COLIFORM ORGANISMS IN KITCHEN GREY WATER AT 20°C

(samples from pipes beneath sinks) after Brandes

isolates were Escherichia coli. In view of the generally accepted indicator status of this organism in environmental pollution, it is apparent that a potential health hazard can be assigned to grey water effluents.

In summary, the bacterial quantities from pleasure-boat grey water appear to be surprisingly high, and provide cause for concern. The figures presented in this study represent the best data available, but should be viewed within the concept of on-shore waste generation. Because off-shore generation should be reasonably close to on-shore on a per-capita basis, as noted under Item 3.4.3, the potential for contamination of recreational waterways is certainly there. This position seems to be supported by a recent intensive testing program at Rotary Beach Park, Fenelon Falls by the District Health Unit in 1985, resulting in the restriction of boats there in the summer of 1986.

3.4.4 Maximum Number of Pleasure Boats Resulting in Excessive Bacterial Contamination

Using the available data for grey water contribution to bacterial contamination of the receiving waters, a model was developed to estimate the maximum number of pleasure boats allowed to discharge their grey water from kitchen, handbasin, showers, etc. into a quiet bay, for 24 hours, without exceeding the permissible concentration of fecal coliform organisms for direct-contact recreation. The fecal coliform indicator is used in the calculations because it is more significant and reliable than total coliform, particularly for enterically polluted waters. Some provisions have been made as follows:

- The background contamination of the lake water, with fecal coliform organisms, is zero.
- The lake has a low water exchange, and is not undergoing any significant mixing of water (from strong turbulence, etc.)
- The effective depth of water in the lake is 1 m which represents a reasonable zone of boating activity (grey water discharge, etc.) and a normal depth for swimming.
- The maximum limit of fecal coliform organisms in the lake water for direct-contact recreation is 100/100 ml or $2 \times 10^6/m^3$ (per guidelines ref. 3)

- The number of fecal coliform organisms generated by one person per day is 12.6×10^9 (the greatest number from Table 3-3, i.e. under Grey Water, Smith et al.)
- The fecal coliform die-off rate is not considered because of the short time periods involved.

The total number of fecal coliform organisms discharged from the boats into the water of a quiet bay should be less than the maximum limit of fecal coliform organisms in the water permissible for direct-contact recreation. (i.e. fecal coliform organisms discharged ≤ fecal coliform organisms permissible)

Using following symbols:

A = area of quiet bay (km^2)
D = effective depth of quiet bay (m)
B = allowable number of boats
P = average number of people in one boat,
one can express the above relation as:

$$B \times P \times [12.6 \times 10^9] \leq A \times 10^6 \text{ m}^2 \times Dm \times [2 \times 10^6/m^3] \quad \ldots\ldots\ldots\ldots \quad (1)$$

The allowable number of boats: $B \leq \dfrac{A \times D \times 158.7}{P}$

Example: A quiet bay with an area A = 2 km^2. and effective depth D = 1 m, loaded with boats carrying on an average 4 people each, should/allow:

$$B \leq \frac{2 \times 1 \times 158.7}{4} \cong 79 \text{ boats}$$

to stay for 24 hours, and discharge the grey water from kitchen and bathroom without causing contamination of lake water above the permissible level.

Note: If the background contamination of the lake water was higher than zero (e.g. 50/100 ml or $5 \times 10^5/m^3$) the allowable coliform number $2 \times 10^6/m^3$ in

equation (1) would be reduced as follows: $2 \times 10^6/m^3 - 0.5 \times 10^6/m^3 = 1.5 \times 10^6/m^3$. This in turn would reduce the number of boats to 59 (i.e. $79 \times \frac{1.5}{2.0}$)

It is concluded that grey water pollution is of concern in a quiet bay because the allowable number of average (4-person) boats is within the realm of experience in the height of summer season.

3.4.5 Summary

a) A two-year study by Udell[2] indicates that bacterial pollution of marinas or confined embayments not exhibiting complete or near complete flushing is directly proportional to the number of boats in the area.

b) Some strains of E. coli survive in water for lengthy periods of time - typically days, but up to months.

c) A study by Olsson et al.[14] shows that the concentrations of total and fecal coliform organisms in grey water from kitchens, bathrooms (tubs, sinks) are equal and in some cases higher, than concentrations of coliform organisms in black (toilet) wastewater.

d) The bacterial quantities in household grey water are surprisingly high, and provide cause for concern. The position for pleasure-boat grey water being similar is supported by recent testing at Fenelon Falls, and should be confirmed by further monitoring of sensitive areas.

e) Simple calculations have shown that only a limited number of boats can be allowed to discharge their grey water directly into the lake water without exceeding the maximum limit of total and fecal coliform concentrations permitted by Canadian Guidelines for direct contact recreation.

A formula for calculating the allowed number of boats for a given lake area and water depth, is given in the report.

3.5 CHEMICAL CONTAMINATION OF LAKES AND RIVERS DUE TO HUMAN ACTIVITY

3.5.1 General

Many problems in lakes and rivers are attributed to municipal and industrial organic wastes. Part of the pollutional contribution is due also to the organic matter and nutrient salts in wastewater discharges from commercial and recreational vessels. The main characteristics of these wastes which are of significance in estimating the degree of wastewater pollution are: the biochemical oxygen demand (BOD) of the organic matter, the suspended solids (SS), the nutrient salts concentrations, and the pathogenic bacterial contamination.

The decomposition of the organic matter by bacteria results in utilization of the dissolved oxygen in the water. The replacement of oxygen, mostly by reaeration occurs through the water surfaces exposed to the atmosphere. Unpolluted water maintains in solution the maximum quantity of dissolved oxygen which is in equilibrium with partial pressure of oxygen in the atmosphere. When oxygen is removed from solution, an imbalance is created and the deficiency is made up by the atmospheric oxygen passing into the solution.

An increase in the concentration of organic matter stimulates the growth of bacteria in the water and the oxidation proceeds at an accelerated rate. The concentration of organic matter can be so great that the receiving water body can be completely devoid of dissolved oxygen.

The reduction of the amount of oxygen in the water serves as an indicator of the organic pollution expressed in terms of its biochemical oxygen demand (BOD). The BOD may be defined as that quantity of oxygen required during the stabilization of decomposable organic matter by aerobic biological action. The most usual criterion is the five day's biochemical oxygen demand BOD_5, i.e. the amount of oxygen consumed by biochemical processes, during a five-day period at a temperature of 20°C.

The total elimination of oxygen from the lowermost layer of water (hypolimnion*) during the summer months, and the accumulation of considerable quantities of nutrients such as phosphorus and organic nitrogen compounds from the wastewater, results in the disappearance of fauna inhabiting the deeper regions of the lakes, as well as of the higher species of fish. Floating algae proliferate along shores of watercourses causing deterioration of the quality of the water.

Such changes may have serious practical repercussions: impaired conditions from health and aesthetic standpoints leading to increasing difficulty in direct use of water for drinking and recreational purposes (swimming, boating, etc.), unpleasant taste and odour, massive fish mortality and losses for anglers and fisheries.

The stability of the organic substances, i.e. their resistance to bacterial attack depends on nutrient (P and organic N) load from wastewater which affects the oxygen metabolism of the water. Phosphorus and nitrogen are considered key elements in causing excessive water fertilization which in turn brings about an abundant growth of algae and other aquatic plants. Vollenweider[22] and Thomas[23] demonstrate numerous examples of eutrophication of lakes in North America and Europe caused by phosphorus and other nutrients entering the lakes from different sources. Kolenbrander[24] showed that 38 per cent of the total accumulation of phosphorus in fresh surface waters in The Netherlands comes from release of unpurified wastewater.

Gupta[9] studied the chemical aspects of a very highly polluted lake in India with a heavy input of domestic sewage and organic pollutants. The author found high concentrations of dissolved oxygen (DO) near the surface and low concentrations at the bottom waters. The BOD_5 values always exceeded 6.0 mg/L, NO_3-N and PO_4-P varied from 1100 to 0.75 mg/L and 0.018 to 0.153 mg/L respectively. The author stated that the above concentrations were sufficient to cause blooming of certain phytoplanktons on occasion.

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* below 6 m depth

A recent (1985) Swedish study[25] dealing with environmental aspects of sewage treatment and disposal for coastal towns, reports that increased inputs of nutrients to marine coastal areas over the last decades have created a basis for eutrophication of the waters surrounding Sweden. Relatively low water exchange in these vertically stratified and almost non-tidal waters and decreased oxygen concentration in bottom waters, lead to mortalities of benthic animals and to a decrease in fish catches. The effects were first noted in the Baltic Sea, but are now obvious also in the eastern coastal areas of Denmark and Sweden.

In many countries, there are virtually no standards or regulations limiting the maximum permissible level of chemical and bacterial contaminants in effluent being discharged into surface waters from houses or boats.

The wastewater treatment plants in the U.S.A. and Canada have adopted a permissible concentration of phosphorus in effluents for the Great Lakes of 1.0 mg/L (as P) in accordance with the recommendations of the 1972 Canada-United States Agreement on Great Lakes Water Quality[26]. The Swedish law governing environmental protection, limits the phosphorus (P) concentrations in effluents to about 0.5 mg/L (as P)[27].

Little attention was given to the pollutional effects of wastewater discharged from boats and other vessels where the nutritional and hygienic customs or the physiological needs of the users are similar to the habits of normal land residents.

The average daily discharged wastewater quantities were found to be about 182 litres per person per day (L/p.d) for a household, and 191 L/p.d for a Great Lakes cargo carrier as noted previously in Table 3-4. The household wastewater usually contains the toilet wastes or the so-called "black water" mixed with the "grey water" which includes the discharges from the kitchen sink, tub and shower, bathroom lavatory, and clothes washing machine. Table 3.4 shows the grey water and black water usage (in L/p.d) by household

residents and by crew members of a large cargo vessel published by different researchers.

According to the International Joint Commission[28], approximately 450 000 boats and vessels of different sizes, both commercial and private, including pleasure craft used the waters of Lake Erie, Lake Ontario, and the St. Lawrence River in 1968. The estimate does not include the countless hundreds of recreational watercraft which are brought by trailers, into lake basins from all parts of Canada and the United States.

At the end of 1967, there were some 369 000 pleasure boats licenced in the Province of Ontario and of these approximately 33 000 were suitable for cruising and provided overnight accommodation.

To get a clearer idea about the amount of pollutants discharged into the water from commercial and pleasure craft, it seems useful to look more closely at the daily or yearly pollutional contribution of one person.

According to literature[22], each person generates daily about 1.33 kilograms of excrement, of which 0.13 kg is in a solid and 1.2 kg in a liquid form. This translates to about 1.0 kg per person per year of phosphorus and about 4.0 kg per person per year of nitrogen, and, when not retained in a ship's holding tank, these nutrients contribute to lake eutrophication as discussed earlier. The effective phosphorus loading is about 2 or 3 times higher than the physiological loading, the excess primarily attributed to detergents having a phosphorus content of about 10%.

The specific quantities of the main chemical contaminants (per person per day) discharged from a household is shown in Table 3-6, and can also be assumed from a boat. The current Ontario Discharge of Sewage from Pleasure Boats Regulation[29] does not prohibit the discharge of grey water from

TABLE 3-6

QUANTITIES OF CHEMICAL CONTAMINANTS
IN GREY AND BLACK HOUSEHOLD WASTEWATER[1]

	After Brandes (Ref. 17)				After Olsson et al. (Ref. 14)			
			% Division				% Division	
	Grey Water[2]	Black Water	Grey	Black	Grey Water[2]	Black Water[3]	Grey	Black
Total phosphorus (as P)	0.2	2.2	8	92	0.9	1.6	36	64
Soluble phosphorus (as P)	0.02	1.79	1	99	-	-	-	-
Total Solids	66.5	73.3	48	52	58	53	52	48
Suspended Solids	20.4	9.1	69	31	16	30	35	65
BOD_5	18.8	11.0	63	37	22	20	52	48
TOC	15.8	11.5	58	42	14	25	36	64
COD	46.1	30.5	60	40	47	72	39	61
Ammonia (as N)	0.2	16.3	1.2	98.8	-	-	-	-
Total Kjeldahl (as N)	1.4	18.1	7	93	0.9	11	8	92

1 All quantities are in grams per person per day (g/p.d.).

2 The grey water contains kitchen and bathroom wastewater only. Phosphorus-free detergents were used in the house in Brandes' study; phosphorus detergents were used in the house studied by Olsson et al.

3 A vacuum toilet was used in Olsson's study.

pleasure boats directly into receiving waters. Wollenweider[22], in his comprehensive but dated report based on various studies on phosphorus and nitrogen contents in waters of five North American lakes, presented the following total P content in the water: Lake Superior 5 mg/m^3, Lake Michigan 13 mg/m^3, Lake Huron 10 mg/m^3, Lake Erie 61 mg/m^3 and Lake Ontario 75 mg/m^3. The organic nitrogen content in lake water was from 80 to 220 mg/m^3.

Waters with total phosphorus concentrations below 20 mg/m^3 may be regarded as being within acceptable limits, as defined in the M.O.E. Water Management Guidelines (Blue Book).

The contribution of chemical contaminants (per person per day) presented in Table 3-6 seems rather small and insignificant when considering the huge amounts of water in lakes or rivers. However, during the summer boating season the pleasure craft are often concentrated along the lakeshores and within small bays, with adults and children living in the boats for extended periods of time. Although most boats have holding tanks for black water retention, grey water is generally discharged into the recreational waters.

Experimental studies in Canada, Sweden and the U.S.A. have shown relatively high concentrations of chemical and bacterial contaminants in grey water. It is evident that the discharge of grey water into lakes and rivers creates a danger similar to the release of the black water from toilets, the latter being restricted by law.

The experimental results of grey water studies are presented and discussed in the following subsections.

3.5.2 Discussion of Chemical Contamination Results Obtained From Grey and Black Water Investigations

Biochemical Oxygen Demand (BOD_5)

As mentioned previously, the Biochemical Oxygen Demand (BOD_5) of the organic matter in wastewater is one of the most important indicators of pollution. Table 3-7 presents the concentrations of BOD_5 in grey and black water from two households (columns 1 and 2), and from a Great Lakes cargo carrier (column 3). The concentrations are expressed in the following units: milligrams per litre (mg/L), and grams per person per day (g/p.d). The latter, called also "specific pollution", is a more representative indicator because it shows the weight of pollution generated by one person daily independent of where the person is located (boat or household) or the amount of water used for getting rid of the polluting matter.

Column 1 of Table 3-7 shows the average concentrations of BOD_5 in effluents from (a) kitchens, bathrooms, laundries and (b) toilets of 25 apartments of a building reported by Olsson et al.[14] of the Swedish Institute for Building Research. A Liljendahl vacuum toilet system was installed in the building using only 8.5 litres of water per person per day as compared to 65.3 L/p.d used in an average household toilet or to 68.2 L/p.d used in a cargo carrier toilet. Due to this low water use by the vacuum toilet, the BOD_5 in Olsson's report expressed in mg/L is relatively high (2317 mg/L), but - when expressed in g/p.d - the BOD_5 is 20.0 g/p.d or almost the same as in Laak's household study[19] (23.5 g/p.d) and lower than in the toilet effluent from the cargo carrier reported by Pancuska[15] (55.7 g/p.d). In comparing the BOD_5 of grey and black water, the grey water portion was 48.9%. The effluent from the galley/kitchen contributed 56.6% of the BOD_5 in the grey water. So, the contamination potential from grey water is high, and the major contribution is from the galley/kitchen.

TABLE 3-7

CONCENTRATIONS OF BOD_5 IN GREY AND BLACK WASTEWATER*

Source of Contamination	1		2		3		4	
	Olsson et al. (Ref. [14])		Laak (Ref. [19])		Pancuska (Ref. [15])		Average	
	mg/L	g/p.d	mg/L	g/p.d	mg/L	g/p.d	g/p.d	%
Kitchen or Galley	Kitchen 324	17	Kitchen 175	9.2	Galley** 506	27.6	17.9	27.7
Bathroom	76	5	Bathtub 120	6.2	Shower 170	11.6	8.2	12.7
			Bathroom Sink 372	1.9				
Laundry	349	3	45	7.9	-	-	5.5	8.5
Toilet (black water)	Vacuum Toilet 2317	20	313	23.5	817	55.7	33.1	51.1
						Total	64.7	100.0

* Data in columns 1 and 2 are from household grey water studies, data in column 3 are from a Great Lakes bulk cargo carrier study.

** A grinder pump was serving the galley.

Suspended Solids (SS)

The suspended solids (SS) concentrations are another important indicator of wastewater pollution.

Table 3-8 presents the concentrations of SS in grey and black water from one household (column 1) reported by Olsson et al.[14] and from one cargo carrier on which the wastewater characteristics were tested twice - by Pancuska et al.[15] (column 2) and by Smith et al.[16] (column 3). Again, the very high concentration of SS from the toilet shown in column 1 (3574 mg/L) is due to the vacuum system using relatively small amounts of water for the toilet flushing. Analysing the concentrations given in grams per person per day, one finds that the grey water (from kitchen or galley, bathroom and laundry) contributes 65.6% of the suspended solids in the total wastewater. The SS contribution of the galley/kitchen to the grey water share is 88.3%, the bathroom - 10.4%, and the laundry - 1.3%.

TABLE 3-8

CONCENTRATIONS OF SUSPENDED SOLIDS (SS) IN GREY AND BLACK WASTEWATER*

Source of Contamination	1		2		3		4	
	Olsson et al. (Ref. [14])		Pancuska (Ref. [15])		Smith et al. (Ref. [16])		Average	
	mg/L	g/p.d	mg/L	g/p.d	mg/L	g/p.d	g/p.d	%
Kitchen or Galley	Kitchen 253	13.0	Galley** 1636	89.2	Galley** 2050	111.8	71.3	57.9
Bathroom	49	3.0	Shower 304	20.7	Shower 22	1.5	8.4	6.8
Laundry	179	1.6	-	-	46.5	0.63	1.1	0.9
Toilet (black water)	Vacuum Toilet 3574	30.0	804	54.8	-	-	42.4	34.4
						Total	123.2	100.0

* Data in column 1 are from a household grey water study, data in columns 2 and 3 are from a Great Lakes bulk cargo carrier study.

** A grinder pump was serving the galley.

Total Phosphorus (P)

The effect of phosphorus (P) from wastewater on the eutrophication of lakes was discussed previously in this Section.

A comprehensive report on the above subject was published by Volleweider[22] discussing almost all aspects of the effect of phosphorus and nitrogen on lake eutrophication. Unfortunately, no attention was given in the above report to nutrients (P&N) entering the lakes from boats, and no mention was provided on P&N entering the lakes from grey water sources.

Table 3.9 presents the concentrations of total phosphorus (as P) in grey and black water from two households (columns 1 and 2), and from the previously mentioned cargo carrier (column 3). The concentrations are expressed in both mg/L and g/p.d.

The highest concentration of total P was observed in the toilet effluent (190.0 mg/L) apparently because of the vacuum system used in Olsson's study[14]. The laundry effluent also showed high concentrations of P (155 mg/L) due to the detergent used by the household. The concentration of phosphorus in galley/kitchen effluents ranged from 4.2 mg/L in the house studied by Laak[19] to 22.4 mg/L in the effluent from the galley. The concentrations of phosphorus in the bathroom effluents in the two houses were 10.3 mg/L and 16.2 mg/L, and in bathroom of the carrier 10.0 mg/L. Column 4 of Table 3-9 shows the concentrations of P (in g/p.d) in the effluent from separate fixtures. The contribution of P from grey water was 60.7% as compared to black water with a concentration of P 39.3%. The effluent from the laundry contributed 34.8% of the phosphorus in the total wastewater (grey + black), and 57.3% of the phosphorus in the grey water. The high percentage of phosphorus in the laundry effluent can be attributed to the phosphorus in detergents. The average concentrations of phosphorus in the effluents from the galley/kitchen and from the bathroom were 0.52 g/p.d and 0.56 g/p.d respectively.

TABLE 3-9

CONCENTRATIONS OF TOTAL PHOSPHORUS (as P) IN GREY AND BLACK WASTEWATER*

Source of Contamination	1		2		3		4	
	Olsson et al. (Ref. [14])		Laak (Ref. [19])		Pancuska (Ref. [15])		Average	
	mg/L	g/p.d	mg/L	g/p.d	mg/L	g/p.d	g/p.d	%
Kitchen or Galley	Kitchen 6.5	0.3	Kitchen 4.2	0.06	Galley 22.4	1.2	0.52	12.5
Bathroom	10.3	0.6	Bathtub 0.3	0.01	Shower 10.0	0.68	0.56	13.4
			Bathroom Sink 15.9	0.4				
Laundry	155.0	1.3	55.9	1.6	-	-	1.45	34.8
Toilet (black water)	Vacuum Toilet 190.0	1.6	25.3	2.1	18.1	1.23	1.64	39.3
						Total	4.17	100.0

* Data in columns 1 and 2 are from household grey water studies, data in column 3 are from a Great Lakes bulk cargo carrier study.

On an average, the total amount of phosphorus discharged from a house or from a cargo carrier was found to be about 4.0 g/p.d, or about 1.5 kilograms per person per year.

Total Kjeldahl Nitrogen (TKN)

According to "Standard Methods"[30] for examination of water and wastewater, the sum of total organic nitrogen and ammonium nitrogen is called Total Kjeldahl Nitrogen (TKN). The effect of nitrogen (N) as a nutrient affecting the eutrophication of lakes was discussed earlier.

Ammonium nitrogen in black water derives, first of all, from urine (85% of N) and from fecal matter (15% of N). In grey water, the nitrogen comes primarily from the use of cleaning agents containing ammonium.

The daily per capita loading from grey and black wastewater combined is about 10.8 grams[22], or about 4.0 kilograms per person per year.

Table 3-10 presents the concentrations of Total Kjeldahl Nitrogen (as N) in grey and black water from one household (column 1) and from the previously mentioned cargo carrier (columns 2 and 3).

The unusually high concentration of nitrogen (N) in the toilet (black) wastewater in Olsson's study (1280 mg/L) is a result of using a vacuum toilet system with little water for flushing the toilet. The concentration of nitrogen in black water from a toilet with a regular flushing system was 153 mg/L[8] and 140 (EPA)[31]. The concentration of nitrogen in the black water from the cargo carrier was 90 mg/L (column 2).

As follows from the Olsson et al. report (column 1), 91% of the nitrogen expressed in g/p.d comes from the black water, about half of the grey water in nitrogen originates from the kitchen.

TABLE 3-10

CONCENTRATIONS OF TOTAL KJELDAHL NITROGEN (TKN) (as N)*
IN GREY AND BLACK WASTEWATER

Source of Contamination	1		2		3		4	
	Olsson et al. (Ref. [14])		Pancuska (Ref. [15])		Smith et al. (Ref. [16])		Average	
	mg/L	g/p.d	mg/L	g/p.d	mg/L	g/p.d	g/p.d	%
Kitchen or Galley	Kitchen 11.4	0.6	Galley 41.3	2.3	Galley 204	11.1	4.67	33.3
Bathroom	5.6	0.3	Shower 11.2	0.8	Shower 4.2	0.3	0.47	3.3
Laundry	23.2	0.2	-	-	33.2	0.5	0.35	2.5
Toilet (black water)	1280.0	11.0	90.0	6.1	-	-	8.55	60.9
						Total	14.04	100.0

* Data in column 1 are from a household grey water study, data in columns 2 and 3 are from a Great Lakes bulk cargo carrier study.

On an average (column 4), the contribution of the toilet (black) water to the total nitrogen from the household and bulk cargo (in g/p.d) was 60.9%. Eighty-five per cent of the nitrogen in the grey water comes from the galley/kitchen, the other 15% from the bathroom and laundry combined.

3.5.3 Effect of Nutrients From Grey Water On Recreational Water

A formula determining the allowable number of pleasure boats with regard to avoiding the contamination of recreational water with excessive numbers of fecal coliform organisms - was presented previously.

The formula, expressed in total number of people on boats, is set out as follows:

$$BP = 158.7 \times A \times D$$

where: A = quiet bay area (km^2), D = effective depth of bay (m), B = number of boats, and P = average number of people on a boat.

An attempt will be made to calculate the daily amount of phosphorus and nitrogen discharged into the quiet bay by the grey water from the above "allowable" number of boats, and from the increase in concentration of the chemical (P and N) in the recreational water.

The average amount of total phosphorus discharged in the grey water was found to be 2.53 g/p.d, and of the total Kjeldahl nitrogen - 5.49 g/p.d (Table 3.11).

The Ontario Ministry of the Environment Guidelines of 1984[32] recommend a limit of 10 mg/m^3 of total phosphorus concentrations for a high level protection of lakes against aesthetic deterioration. The amount of total phosphorus discharged daily with the grey water from the previous calculated allowable number of boats is:

TABLE 3-11

AVERAGE CONCENTRATIONS OF MAIN CHEMICAL CONTAMINANTS IN GREY AND BLACK WASTEWATER

	BOD_5		Suspended Solids		Phosphorus		Nitrogen	
	g/p.d	%	g/p.d	%	g/p.d	%	g/p.d	%
Grey Water	31.6	48.9	80.8	65.6	2.53	60.7	5.49	39.1
Black Water	33.1	51.1	42.4	34.4	1.64	39.3	8.55	60.9
Total	64.7	100.0	123.2	100.0	4.17	100.0	14.04	100.0

Values from Tables 3-7 through 3-10.

$$BP \times 2.53 \text{ g}$$

$$\text{or } 158.7 \times A \times D \times 2.53 = A \times D \times 401.5 \text{ g}$$

The volume of water (V) in a quiet bay of area A km^2 and an effective depth of D m is:

$$V = A \times 10^6 \text{ m}^2 \times D \text{ m} = 10^6 A \times D \text{ m}^3$$

Consequently, the concentration Cp of the total phosphorus in the bay water is:

$$Cp = \frac{A \times D \times 401.5 \times 10^3 \text{ mg}}{A \times D \times 10^6 \text{ m}^3} = 0.4 \text{ mg/m}^3$$

i.e. about 25 times lower than the recommended concentration limit for total phosphorus which is 10 mg/m^3.

According to Vollenweider[22], lake water with inorganic nitrogen concentrations in excess of 300 mg/m^3 may be regarded as in danger. The concentration of total nitrogen Cn in the bay water, calculated in the same way as the phosphorus concentration, was Cn = 0.87 mg/m^3, or about 300 times lower than the dangerous level.

As it follows from the above calculations, the main health hazard for contact recreation in boating areas comes, first of all, from bacterial contamination of recreational water with fecal and total coliform organisms from boat wastewater.

The phosphorus, nitrogen and other chemical contaminants such as biochemical oxygen demand and suspended solids entering the recreational water from pleasure boats are insignificant in comparison with other sources of chemical contaminants which are: farm land run-off (where manure and

artificial fertilizers are used), soil erosion, falling leaves, and certain biological sources such as aquatic birds.

3.5.4 Summary

a) Studies of the effect of chemical contaminants in grey water, on the quality of the lake water have shown that the adverse effect is negligible as compared to the bacterial health hazard caused by the same number of boats.

b) The chemical contaminants in grey water include BOD, SS, and nutrients (P and N) - but exclude bacterial.

c) A summary of average chemical concentrations is shown in Table 3-11.

d) Contaminant contribution is primarily related to the number of people - whether on a boat or in a house.

e) BOD from grey water tends to be high (similar to black water), and the main contributor is the galley/kitchen.

f) SS is moderate, and the main contributor is also the galley/kitchen.

g) P is higher in grey water than black water, and the major contributor is the laundry (use of detergents).

h) N is low, the main contributor being various marine or household cleaners.

i) The effect of nutrients (P and N) on recreational water contamination is negligible.

3.6 EFFECTS OF GREY WATER DISCHARGES FROM PLEASURE BOATS

3.6.1 General

Our review of allowable number of pleasure boats in recreational waterways relating to bacterial and chemical contamination is shown previously in Items 3.4.3 and 3.5.3 respectively. The intention of the ensuing development is to determine the estimated bacterial pollution level from a high-season (summer) scenario in a quiet bay, and to sensitize the model for varying scenarios.

3.6.2 Characteristics

The review of related literature and monitoring surveys reveals that little reliable data exists on the characteristics of grey water generated on pleasure boats. However, it is reasonable to assume that the physiological needs of persons on boats for extended periods (e.g. a weekend or longer) are similar to those of persons on land.

The general investigations reported previously in Item 3.4 provide a reasonable determination of bacterial and chemical concentrations from grey water on a grams/person per day basis for use in a pleasure boat pollution scenario.

3.6.3 Quantities

It is reported by rental operators that typical water consumption on a rental houseboat with six to eight persons aboard may range from 40 to 110 L/p.d., a portion of which is used for toilet flushing and discharged to an on-board sewage holding tank. For other types of craft (power cruisers and sailboats) with smaller potable water tanks, consumption would be somewhat less - in the range of 25 to 75 L/p.d.

3.6.4 Waterway Flow-Through and Quality

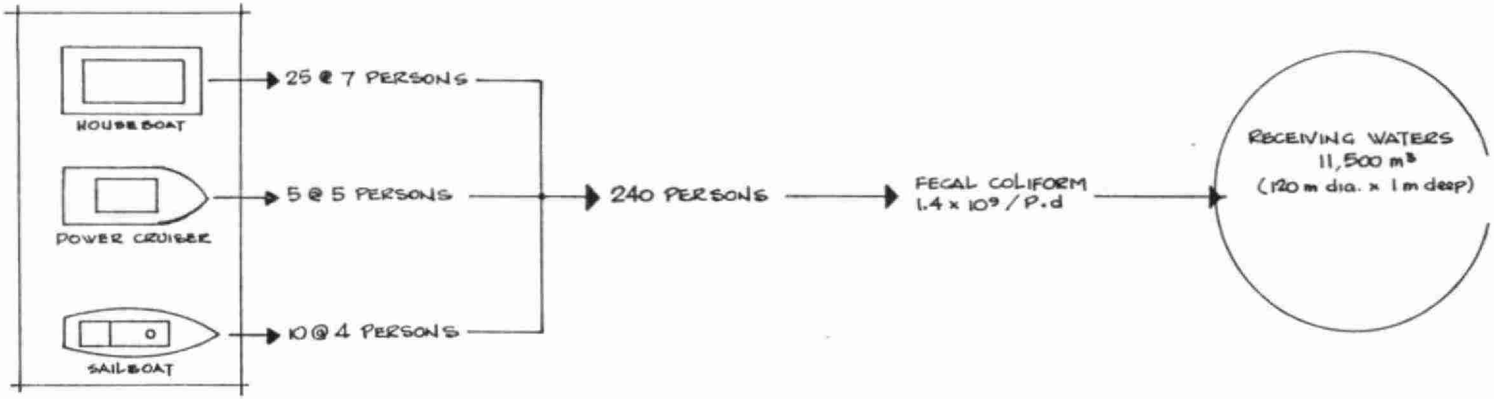
It is recognized that flow-through in recreational lakes and waterways would tend to reduce the impact of grey water discharges from pleasure boats by providing dilution of contaminants, depending on the quality of the incoming flows.

On the Great Lakes system, continuous flow-through occurs due to hydraulic control exercised during ice-free periods to maintain acceptable water levels in the St. Lawrence Seaway. In contrast, for example, flow-through in the Trent-Severn System is determined primarily by runoff of surface water (rain, melting snow) directly into the waterway, and from rivers and streams. The period of lowest runoff occurs during the warm, dry summer season when pleasure boat use is highest.

3.6.5 Pleasure Boat Bacterial Pollution Scenarios

It is useful to evaluate a number of cases as a means of establishing theoretical levels of bacterial contamination of recreational waters from pleasure boat grey water discharges.

The data used to generate pollutional scenarios for various bodies of water have been presented previously in Item 3.4.3. Figure 3.2 presents the basis for development of a high-season model for bacterial loadings in a small, quiet bay with a large number of boats. Also shown on the figure is a Pollution Sensitivity Chart showing results obtained in five cases with varying parameters such as, flow-through, bay area, mixing depth, etc. Refer to Table 3-12 for a complete listing of all sixteen cases developed.



$$\text{FECAL COLIFORM CONTRIBUTION} = \frac{\text{NO. OF PERSONS} \times \text{COUNT / PERSON} \cdot \text{DAY}}{\text{VOLUME OF RECEIVING WATERS}}$$

POLLUTION SENSITIVITY CHART

CASE	TOTAL NUMBER OF BOATS	TOTAL NUMBER OF PERSONS	UNIT PRODUCTION OF FECAL COLIFORM (COUNT / P.d)	RECEIVING WATERS							
				AREA (m^2)	DEPTH (m)	VOLUME (m^3)	FECAL COLIFORM BACKGROUND CONCENTRATION (COUNTS/100mL)	FLOW-THROUGH RATE (m^3/hr)	FECAL COLIFORM DIE-OFF RATE (hr^{-1})	DAY-1 FECAL COLIFORM CONCENTRATION (COUNTS/100mL)	DAY-2 FECAL COLIFORM CONCENTRATION AFTER DIE-OFF (COUNTS / 100 mL)
1	40	240	1.4×10^9	11,500	1	11,500	0	0	0	2922	2922
2	"	"	"	"	3	34,500	0	0	0	974	974
4	"	"	"	"	"	"	50	0	0	1007	1007
6	"	"	"	"	"	"	"	200	0	1007	1007
10	"	"	"	"	"	"	"	"	0.083	1012	138

Figure 3.2 BACTERIAL POLLUTION EFFECT OF GREY WATER DISCHARGE FROM 40 BOATS

TABLE 3-12 SENSITIVITY SCENARIOS

CASE	NUMBER OF BOATS	PEOPLE PER BOAT	TOTAL POPULATION	UNIT PRODUCTION (fecal coliform/c/d)	RECEIVING WATER AREA (m2)	RECEIVING WATER DEPTH (m)	RECEIVING WATER VOLUME (m3)	BACKGROUND CONCENTRATION (COUNTS/100ml)	FLOW-THROUGH RATE (m3/hr)	FLOW-THROUGH CONCENTRATION (COUNTS/100ml)	DIE-OFF RATE (hr-1)	DAY-1 FECAL COLIFORM CONCENTRATION (COUNTS/100ml)	DAY-2 FECAL COLIFORM CONCENTRATION (COUNTS/100ml)
1	40	6	240	1.4×10^9	11500	1	11500	0	0	0	0	2922	2922
2	40	6	240	"	11500	3	34500	0	0	0	0	974	974
3	40	6	240	"	11500	1	11500	50	0	0	0	2955	2955
4	40	6	240	"	11500	3	34500	50	0	0	0	1007	1007
5	40	6	240	"	11500	1	11500	50	200	0	0	2955	2965
6	40	6	240	"	11500	3	34500	50	200	0	0	1007	1007
7	40	6	240	"	11500	1	11500	50	200	50	0	2969	2969
8	40	6	240	"	11500	3	34500	50	200	50	0	1012	1012
9	40	6	240	"	11500	1	11500	50	200	50	0.083	2969	405
10	40	6	240	"	11500	3	34500	50	200	50	0.083	1012	138
11	40	6	240	"	11500	1	11500	0	200	50	0.083	2935	401
12	40	6	240	"	11500	3	34500	0	200	50	0.083	979	133
13	40	6	240	"	11500	1	11500	0	0	50	0.083	2922	399
14	40	6	240	"	11500	3	34500	0	0	50	0.083	974	133
15	40	6	240	"	11500	1	11500	0	0	0	0.083	2922	399
16	40	6	240	"	11500	3	34500	0	0	0	0.083	974	133

3.6.6 Evaulation of Pollution Scenario Results

The review of the literature previously described in Section 3.4.2 indicates that high levels of coliform bacteria contamination have been observed in grey water. Little information is available on the pleasure boat side, but that which is relates to grey water contamination from apartment buildings, residences, and large marine vessels. The total per capita contribution of coliforms to a receiving water is dependent upon the water use and lifestyle characteristics of the population. In cases where water availability is limited, such as in a pleasure boat, personal hygiene and other practices may differ from those of the population observed in the literature. However, the actual limitation of water availability may be augmented by using the water of the waterway for non-potable uses. In addition, any decrease in the frequency in personal washing may be augmented by an increase in the frequency of swimming. Body contact recreation may be an important source of coliform contamination. In summary, although there is no direct information in the literature regarding the bacterial characteristics of grey water from pleasure boats, the data available from other sources may be used, and the probability is that the overall per capita contribution would be approximately the same due to the total net effect of lifestyle similarities. Accordingly, the data presented by Olsson[14] and Brandes[17] can be used in this study to determine the possible levels of contamination due to pleasure boat grey water discharges.

The potential for grey water contamination is assessed in this study by utilizing a series of use-scenarios for a small embayment. Each scenario includes a total of 240 people in 40 boats anchored in an 11,500 m^2 bay.

This area is adequate to accommodate the number of boats in the scenario in close quarters. It is not unusual for boats in bays to be anchored or rafted together so as to create quite high population densities. From the literature identified previously, this population is expected to contribute 1.4×10^9 coliforms per capita/day to the water of the bay.

The final concentration of bacteria in the bay is a function of the volume of bay water, the background concentration, the flow-through rate, and the local coliform die-off rate. The volume, and is therefore governed by factors such as temperature and bathymetry. For this scenario two mixing depths, and hence two mixing volumes, are used. The one meter depth was selected as the critical case for either a very shallow bay or a deeper quiescent bay where the warmer, buoyant grey water would be expected to remain near the surface of the water-mass. The 3 metre mixing depth represents a completely mixed, deeper bay typical of small boat anchorages.

The background concentration of coliform is an important component of the final coliform concentration. For this scenario a value of 0 counts/100 ml was chosen to represent a pristine bay, and a value of 50 counts/100 ml was chosen as a mildly contaminated level. The flow-through rate is a representation of the net amount of flushing of the bay due to tributary inflow and exchange with the larger waterbody. Flow-through is represented here as a tributary flow of 0 and 200 m^3/hr. The local coliform die-off rate is a function of many variables and has been found to vary widely from location to location. The value chosen (0.083/day) represents the higher range of a set of values reported by the U.S. Army Corps of Engineers for Lake Ontario. In choosing this high value, a level of conservatism is injected into the calculation.

The results of this analysis are presented in Table 3-12, and illustrate that levels of coliform contamination of the waters of the bay are higher after one day than the recommended level of 100 fecal coliforms/100 ml[32] for body-contact recreational activities. From the table, it is noted that background concentration and the concentration of the flow-through water is not a significant factor in the final concentration. The mixing depth or dilution volume does have a significant linear effect. The effect of the die-off rate is to reduce the initial concentration of the coliforms over the one day time period selected. However, under all the cases calculated, the concentration of the second day remains higher than the recreational

standard. It should be noted that the second day concentration shown in the table does not include inputs from the boats in the bay on the second day. Therefore the true second day concentration would be higher than that shown.

From this scenario, it can be seen that there is a potential for levels of fecal coliform contamination in exccess of the recreational standards in small heavily used embayments. It is noted that these calculations are based on a number of assumptions and, as such, they should be viewed with caution. Local conditions or different per-capita contributions would result in values different from those represented here. The value of actual field data to confirm the situations represented here cannot be over-emphasized.

3.6.7 Summary

a) The physiological needs of persons on boats are generally similar to those of people on land, thereby providing a reasonable basis for determining bacterial and chemical contributions from pleasure boat grey water discharges.

b) Water flow-through in recreational waterways, such as the Trent-Severn System, is lowest during the peak boating season - resulting in minimal dilution effect.

c) High-season model for bacterial loadings in a small, quiet bay was developed, and sensitized using varying parameters.

d) Evaluation of the high-season pollution scenario cases indicates that there is potential for relatively high bacterial contamination in heavily used embayments.

e) The bacterial effects from pleasure boat grey water discharges should be confirmed as soon as possible by a field monitoring program in sensitive waterways.

3.7 EFFECTS OF BOAT TYPES AND DENSITIES

3.7.1 Boat Types

From the foregoing discussions, it is apparent that the contamination effects of pleasure boat grey water discharges relate primarily to extent of accommodation, on-board amenities, and area of use. These are developed as follows:

Boat Type	Typical Accommodation (persons)	Typical Amenities	Areas of Use	Estimated % of Time in Area
Houseboat	up to 10	full kitchen shower/bath toilet, lav., fridge	- protected rivers, lakes and canals	95
			- open water of inland lakes or Great Lakes	5
Power Cruiser	up to 7	full kitchen, shower, toilet, lav., fridge	- protected rivers, lakes and canals	60
			- open water of inland lakes or Great Lakes	40
Sailboat	up to 5	small kitchen lav., toilet	- Great Lakes	70
			- open waters of inland lakes	15
			- protected rivers, lakes and canals	15

Based on the above, it is possible to prioritize the contamination contribution from various types of pleasure boats in particular locations as follows:

i) larger houseboat in protected rivers, quiet bays, and smaller lakes

ii) power cruiser (or smaller houseboat) in protected rivers, quiet bays, and smaller lakes

iii) sailboat in protected rivers, quiet bays, and smaller lakes

iv) any pleasure boat (with accommodations) in smaller inland lakes

v) any pleasure boat (with accommodation) in larger lakes and rivers (e.g. the Great Lakes system).

The ability of houseboats to approach the shore and anchor in shallow water presents the additional problem of local contamination of waters most frequently used by swimmers. This would also be the case for some shallow-draft power cruisers and sailboats.

3.7.2 Boat Densities

As previously presented in Item 3.4.4, it is possible to calculate the theoretical maximum number of boats which can be accommodated in a defined area without raising the fecal coliform contamination level above the MOE standard for swimmers and bathers (i.e. 100 counts/100 ml). The number of boats determined to be acceptable for the example shown provides a first-order approach, and permits a comparison with the more precise results of the various scenarios described in Item 3.6.4. It is evident that, in small quiet bays, the waterway area (volume) available for anchoring or mooring a given number of boats can often exceed the water volume required for acceptable dilution of the discharged grey water.

3.7.3 Summary

a) A literature search for publications on grey water characteristics has shown that only a very limited number of papers on grey water from households is available and almost nothing on grey water discharged from boats and other floating structures. It was assumed that the concentrations of bacterial and chemical contaminants in grey water from boats when expressed in numbers or grams per person per day should be not much different from those in grey water from households. Similarly, it was supposed that the quantitative proportions between kitchen, washroom, and toilet water usage in boats and houses are similar.

b) Contamination effects of various types of pleasure boats are prioritized based on extent of accommodation, typical amenities, and area of use.

c) In small quiet bays, the waterway area (volume) available for anchoring a given number of boats can often exceed the water volume required for acceptable dilution of the discharged grey water.

d) Aspects which should be looked into in the near future include background bacterial levels of selected enclosed receiving waters, boat densities and boat grey water characteristics.

4.0 ALTERNATIVE SOLUTIONS FOR REDUCED POLLUTION FROM GREY WATER, AND RELATED MATTERS

4.1 GENERAL

The alternatives available are outlined as follows:

- do nothing
- impose total restriction on grey water discharges, i.e. full retention.
- impose partial restriction on grey water discharges, i.e. partial retention.
- restrict discharges on either all waterways or designated sensitive waterways.

4.2 REVIEW OF OPTIONS

a) Do Nothing

In light of increasing public concerns on grey water discharge from boats, the option of not imposing some form of restriction is only realistic if it can be shown that the impact of grey water does not significantly affect the quality of the receiving waters.

As discussed previously in Section 3, the literature review and investigation into the characteristics of boat grey water indicates that, where boats congregate in significant numbers in small bays or restricted waterways, the quality of the receiving waters will be impaired from the associated grey water discharges. Subject to

confirmation of the characteristics and effects of grey water by a suitable monitoring program, some form of restriction of these wastewater discharges is indicated unless boat densities in these sensitive waters can be reduced.

Reduction of contamination by retaining the grey water in pleasure boats is considered a realistic approach, since black water holding equipment is already provided in most new boats with overnight accommodation, and could be reasonably extended to include grey water.

b) Full Restriction

Total elimination of pollution from boat grey water discharges requires the retention of all grey water aboard for subsequent removal by a shore pump- out facility.

This would require either more frequent pump-outs of the existing holding tank or increased wastewater retention capacity. The latter could be achieved by adding a new supplemental holding tank, or by installing a new larger replacement tank. It would be necessary to provide for drain traps (odour prevention in the cabin), and also for potential backflow from the holding tank during rough water conditions. For vessels where the shower/ bath drain is lower than the holding tank, an electric or manual pump would be required to transfer the grey water to the tank.

Although not permitted in Ontario, flow-through treatment systems are permitted elsewhere, i.e. certain portions of U.S.A. These commonly macerate the wastewater as an initial step, then disinfect it with hypochlorite or equivalent, and finally discharge it overboard. Some models generate their own hypochlorite by electrolyzing either salt-water or fresh water with salt added, but they require an electrical

energy source of about 1.5 amp-hours (12 VDC) per cycle. Treatment systems tend to be mechanically complicated and require some technical competence by the boat owner to ensure continuous satisfactory operation. A major drawback to these automatic systems is that, in the event the equipment fails or the disinfectant is exhausted, the effluent would be discharged untreated. Equipment costs for a full retention system on a vessel would be less than for the flow-through treatment alternative, however labour costs for retrofitting existing boats would be greater due to restricted space and existing interior bulkheads, cabinetry, etc.

c) Partial Restriction

An overall reduction of grey water contamination can be achieved by eliminating the discharge of all grey water from certain categories of boats, and its most offensive portion (from galley/kitchen) from other types; or by controlling the density of vessels in sensitive waterways.

The density-control method would be most restrictive on those boat types with many people aboard, namely those generating the most grey water. Attempts to restrict the density of boats in sensitive waterways could be met with strong opposition from many boaters who presently are free to travel Ontario waterways virtually unrestricted. Associated with such a restriction would be the problems and costs of providing an effective enforcement staff. A possible method in waterways with locks would be to reduce the number of locking permits issued at any one time, although it is unlikely that much real control of boat numbers would in fact be achieved. It is also doubtful that any vessel requiring a "harbour-of- refuge" could be prevented from entering one. A program of identifying and restricting those boat types generating the most grey water could present difficulties, however it has been

shown previously that grey water pollution is directly related to the number of persons aboard a boat. Thus the boat type having the capability of accommodating maximum people should be highest on the restriction list, i.e. the larger houseboat.

Retention considerations by boat type are outlined as follows:

i) For new pleasure boats, it should be feasible to provide for retaining all grey water since related installation difficulties can be overcome more easily at the construction stage. For example, a boat's design can be adjusted for holding tank balance, piping layout, etc. - so that practicability and capital cost associated with this option appears reasonable.

ii) For existing larger houseboats, it should be readily achievable, in a physical sense, to retain all grey water since their sewage holding tank is usually located beneath the cabin floor making connection of any new drain piping or the addition of extra tankage relatively straightforward.

iii) For other existing pleasure boats, retrofit modifications to the plumbing system would be required to provide for on-board retention of grey water. This would tend to be more difficult as their holding tank is within the hull where space is restricted due to bulkheads, cabinetry, etc. Also, the location of an existing holding tank relative to certain fixtures could require pumping of grey water to the tank in some cases. Thus partial retention of grey water would be more appropriate for this broadest category of pleasure boats.

d) Waterway Categories

There are two categories of waterways which should be considered, namely high-dilution waterways such as most of the Great Lakes, and low-dilution waterways such as the Trent-Severn system. Grey water would tend to be dissipated in the relatively high flows of the Great Lakes, but could build up during high-season in the relatively low flows of quiet inland waterways. Certain Great Lakes waters where dilution is minimal such as the Bay of Quinte could be relegated to the low-dilution category.

In our view, grey water discharges might be reasonably accepted in high-dilution waterways, whereas restrictions would be more suitable in designated sensitive waterways characterized by low volume and dilution. The latter would include the Trent-Severn system, Rideau Canal, Lake of the Woods, Bay of Quinte, Muskoka Lakes, and others identified after further study.

Enforcement would be facilitated in those waterways having locks such as the Trent-Severn System and Rideau Canal where monitoring could be carried out at system entry locks.

4.3 BOAT IMPROVEMENT CONSIDERATIONS FOR RETENTION OF GREY WATER (FULL OR PARTIAL)

4.3.1 General

Improvement options for existing or new boats relate to on-board retention of part or all of the grey water produced. Reference is made to Figure 4.1 showing typical plumbing schematics for power boats and sail boats. (See also Figures 2.2 to 2.7 for typical systems without grey water retention).

4.3.2 Boat Types

a) Houseboats

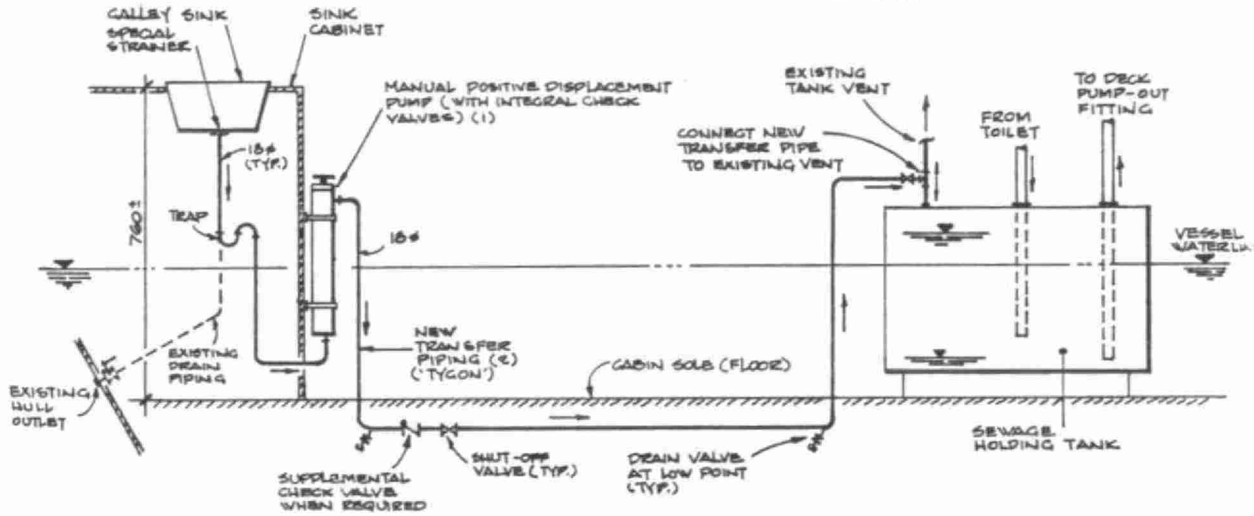
For houseboats, where the holding tank is usually located on the longitudinal centreline below the cabin floor, grey water flow from fixtures to the tank can be accommodated using gravity drains. This would require minimal additional piping, so retrofitting of existing vessels and provision on new boats could be carried out at reasonable cost. As previously discussed, a supplemental holding tank could be added to increase the craft's wastewater retention capacity and reduce frequency of pump-out.

b) Power Cruisers and Sailboats

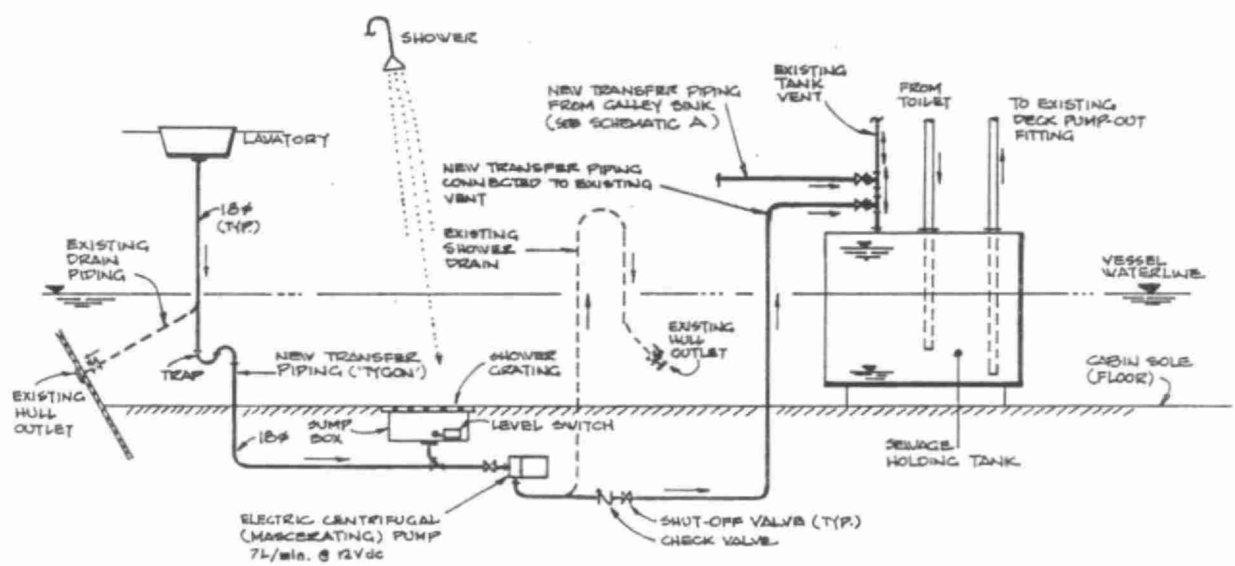
Retention of grey water aboard power cruisers and sailboats requires consideration of additional factors since the holding tank would likely be more remote from the galley sink in comparison with the lavatory and shower. However, because a galley sink drain would usually be above the level of the holding tank, it should be possible to drain the sink by gravity. Otherwise, a small electric macerating centrifugal pump or manual positive-displacement one could be installed to transfer galley wastewater to the holding tank. This would have the added advantages of more positively preventing backflow into the sink and allowing the sink to be drained when the boat is heeled. On larger sailboats having a shower, a sump box with electric pump and level switch has typically been provided to raise the shower wastewater above the boat waterline through a piping loop for direct discharge. This shower pump might be adaptable to also transfer the grey water from the shower (and perhaps the lavatory) to the modified holding tank.

NOTES

1. ALTERNATIVE IS ELECTRIC CENTRIFUGAL (MASCERATING) TYPE.
2. TRANSFER PIPING CAN ALSO BE RUN ABOVE CABIN SOLE, APPROPRIATELY CONCEALED.



Schematic A - PARTIAL RETENTION SCHEMATIC (FOR GALLEY ONLY)



Schematic B - FULL RETENTION SCHEMATIC

Figure 4.1 TYPICAL SCHEMATICS FOR GREY WATER RETENTION ON POWER CRUISERS AND SAILBOATS

4.3.3 Pleasure Boat Upgrading Cost Estimates for Adding Grey Water Retention

a) Existing Smaller Houseboat, Partial Grey Water Retention

(no additional tankage)

- equipment: pipe, fittings, misc.	$ 90
- labour: (out of water) 7 hrs @ $30/hr + misc.	210
	$300

b) Existing Larger Houseboat, Full Grey Water Retention

- equipment: pipe and fittings, incl. traps (37 mm Ø typ), and misc.	$200
- labour: (out of water) 15 hrs @ $30/hr misc.	450
- additional holding tankage: evaluate 200 L (s&i)	350
	$1000

c) Existing Power Cruiser or Sailboat, Partial Grey Water Retention

(no additional tankage)

	Manual	Electric
- equipment: pipe and fittings	$ 90	$ 90
galley drain pump (manual non-clog/electric macerator)	170	275

wiring and controls	-	35
- labour: manual system, 8 hrs @ $30/hr	240	-
electric system, 10 hrs @ $30/hr	-	300
	$500	$700

d) Existing Power Cruiser or Sailboat, Full Grey Water Retention

	man/electric	all electric
- equipment: pipe and fittings	$125	$100
galley drain pump (manual non-clog)	170	245
shower/lav drain pump (small elec)	55	55
add'l holding tank (vent, deck fitting)	200	200
- labour: manual/electric system, 20 hrs @ $30/hr	600	-
all electric system, 20 hrs @ $30/hr	$ -	$600
	$1100	$1200

e) <u>Installations for "New" Boats, Full Retention (s&i @ factory)</u>

. Larger houseboat: add 200 L (approx. 30%) $600

. Power cruiser or sailboat - with galley only, add 30 L (roughly 25% increase) $600

- with galley and shower, add 80 L (roughly 50% increase) $900

4.4 GREY WATER DISCHARGE REGULATIONS

Presently, there is no restriction on the discharge of grey water into Ontario recreational waters from pleasure boats. Regulations in effect for the prevention of pollution from sewage could be modified to include part or all of pleasure boat grey water as has been done in some other jurisdictions previously noted under Item 2.6.3. Implementation and enforcement options of new grey water discharge Regulations are discussed below.

For new vessels, implementation of Regulations restrictions grey water discharge would be directed at boat builders' plants for Ontario-built boats, and at boat brokers' offices for "imported" boats. Where new boats are brought into Ontario by private purchasers, there would be an opportunity for Customs officials to enforce the Regulations. It is noted that when obtaining or transferring a vessel licence, the boat is not visited - but rather a licence is issued based on the owner producing suitable documents proving ownership. Also, when applying for an operator's licence, as required in Toronto Harbour, one does not have to be tested on one's own boat. With reference to the existing grey water discharge regulations in the state of New Hampshire (see Appendix A), it is reported that compliance by boaters has been widespread, since the onus has been placed on commercial marina operators to ensure that boats comply before they are launched into the state's fresh water lakes and waterways each year.

Finally, continuing boat inspection programs, as currently carried out by Ontario MOE, would enhance implementation and enforcement of any new "no-discharge" Regulations - be they full or partial.

4.5 SUMMARY

a) Alternative solutions for reduced pollution from grey water are developed.

b) Boat improvement considerations are outlined together with related cost estimates for retrofitting.

c) Changes in the regulations, together with on-going inspection and enforcement programs by regulating agencies would be required to ensure reasonable compliance with grey water discharge restrictions.

5.0 EVALUATION OF ALTERNATIVE SOLUTIONS

5.1 GENERAL

This Section contains an evaluation of the investigations into the characteristics and effects of grey water discharges from pleasure boats into Ontario recreational waters together with a review of alternative solutions and the associated implications.

5.2 GREY WATER CHARACTERISTICS

The review of data relating to quantity and quality presented previously in Section 3 indicates that grey water discharges from pleasure boats contains significant bacterial contaminants which could result in undesirable contamination of the receiving waters, particularly when boat densities exceed certain limits. Pleasure boat grey water quality characteristics are based on studies of land-based populations, so require confirmation by actual field monitoring.

Quantities of grey water are based on a review of the literature on typical boat potable water storage capacities, and on discussions with various boat manufacturers and houseboat charter firms. As noted in Section 3, bacterial contaminant loadings on receiving waters have been presented in terms of fecal coliform counts per person-day, thus minimizing the importance of actual quantities of grey water from pleasure boats.

5.3 RELATIVE EFFECTS OF GREY WATER DISCHARGES

The pollution effect of grey water discharges on the recreational water has been found to vary with the number and type of boats (persons contributing), the extent of dilution by the receiving waters (volume and flow-through), the fecal coliform die-off rate; and the background fecal coliform count in the receiving waters from other pollution contributors.

A review of the Pollution Sensitivity Chart shown previously on Figure 3.2 and associated Table 3-12 assists in prioritizing the effects of boat types based on location, number of boats, and extent of grey water discharges.

Table 5.1 shows a scoring system for prioritizing the effects of grey water discharge relative to various parameters. It is not intended to be complete, but does give an indication of relative severities. For example, grey water from a houseboat is considered to be more detrimental than from a power cruiser because there are more people (pollution contributors) aboard.

As expected, houseboats in significant numbers located in enclosed (sensitive) waters and having no grey water retention provisions present the most serious bacterial contamination threat to recreational waters. Under similar conditions, and in the same numbers, the effects of power cruisers and sailboats would be less than for houseboats.

5.4 ALTERNATIVE SOLUTIONS

In broad terms, suitable alternative solutions for reducing the impact of pleasure boat grey water discharges are full or partial retention on board boats for disposal ashore. The option of permitting use of on-board treatment systems with overboard discharge of treated grey water effluent is considered to be unsuitable due to equipment efficiency, complexity, maintenance difficulties, significant electrical energy requirements, and high capital and installation costs.

Major aspects associated with any grey water retention scheme are, the extent of application (i.e. all or selected boats, including ones from out-of-province), location where a boat is principally used, age of boat (i.e. will problem be solved by natural attrition), and time allowance for compliance.

Table 5.1

Grey Water Pollution Effect For Various Parameters

Boat Type	Location A Enclosed Waters	Location B Open Waters	Number of Boats A >20	Number of Boats B <10	Grey Water Retention A None	Grey Water Retention B Partial	Grey Water Retention C Full	Score Totals A	Score Totals B	Score Totals C
Houseboat	5	1	5	3	5	3	0	13	9	0
Power Cruiser	3	<1	4	2	4	2	0	9	<7	0
Sailboat	3	<1	4	2	4	2	0	9	<7	0

Scoring Legend for Increased Grey Water Pollution Effect

0 = none
1 = minimal
2 = slight
3 = moderate
4 = significant
5 = high

The requirement for grey water retention on new boats could be met by the installation of the necessary equipment at the construction stage. For existing boats, an extensive inspection/enforcement program would be required by regulatory agencies to ensure widespread compliance.

While the necessity of minimizing the discharge of grey water in sensitive areas is evident, the appropriateness of discharge restrictions for boats operated principally in open waters tends to be vague, therefore the locales where particular types of boats are used needs to be considered when assessing any scheme. For instance, in Lake Ontario, many sailboats are used mainly for "round-the-buoys" club racing and seldom cruise to sensitive areas such as the Trent-Severn Waterway.

In the early 1960's the pleasure boating scene changed considerably with the development of the mass-produced boat constructed of glass-reinforced-plastic. The use of this material resulted in a significant reduction in the capital cost of pleasure boats with a promise of minimum maintenance and long life, resulting in a boating boom. At this time, the usable life of pleasure boats built since the early 1960's is unknown, but it appears to be greater than 25 years so that any reduction of grey water discharges from existing boats from natural attrition is not to be expected. This aspect also applies for commercially built houseboats constructed of modern, long-lasting materials such as aluminum and fibreglass.

Each year, many foreign and out-of-province boats visit Ontario, mainly by crossing the Great Lakes. Of the eight U.S. states where pleasure boats have direct access to Ontario waters (see Item 2.6.2), three (Michigan, Minnesota and Wisconsin) have "no-discharge" sewage regulations similar to Ontario, four (New York, Ohio, Pennsylvania and Indiana) have options of on-board sewage treatment with discharge or no-discharge, and one (Illinois) state prohibits sewage discharge only in designated state reservoirs. From this summary, it is probable that presently there is a large number of visiting U.S. pleasure boats with sewage handling systems which do not meet

existing Ontario standards. In addition to reviewing the suitability of imposing further restriction of grey water discharges from out-of-province boats, the number and locations favoured by visiting boats need to be assessed in order to confirm the existing impact on Ontario recreational waters.

One alternate solution would be to restrict the number of boats allowed to be in sensitive areas at any given time. This approach could theoretically achieve the desired reduction in bacterial contamination. however the monitoring and enforcement of such a "quota" restriction would probably require excessive time and cost expenditures by government agencies. Restricting the densities of pleasure boats requires complex definition of many parameters, and intensive monitoring and enforcement by regulatory agencies. Also, boater resistance to geographical restrictions could be expected to be high. This solution is not considered to be practical from the viewpoint of implementation and enforcement.

5.5 MOST SUITABLE SOLUTION

a) In our view, full grey water retention should be fitted on all new pleasure boats with overnight accommodation, independent of type; and retrofitted on all existing larger houseboats. This would apply to all waterways.

b) On other existing pleasure boats, partial grey water restriction should be imposed on craft using designated sensitive waterways.

The foregoing best alternative reflects the following aspects:

- ease and moderate cost of redesigning retention and plumbing systems for new boats, and the relative ease of ensuring comformance at the manufacturers' plants.

- simplicity and reasonable cost associated with increasing houseboat wastewater retention and modifying their plumbing systems; also, the relative ease of ensuring implementation by licencing and inspection authorities.

- for other existing boats, galley wastewater plumbing retrofits would be more difficult, but still reasonably done, with monitoring carried out to suite by MOE and other authorities.

5.6 SUMMARY

a) An evaluation of alternatives is carried out.

b) The most suitable alternative to reduce the impact of grey water discharges from pleasure boats is to restrict all discharges from new boats (and larger existing houseboats) on all waterways, and other existing boats on sensitive waterways.

c) Impact of grey water discharges from visiting boats (out-of-province and U.S.) should be studied further).

6.0 CONCLUSIONS

Based on the findings of this study on pleasure boat grey water pollution, we conclude that:

a) There is increasing concern from various groups in Ontario over pleasure boat pollution from grey water discharges into recreational waterways.

b) Available data on this subject indicate that bacterial pollution levels from grey water discharges can exceed the safe limit for recreational water uses (swimming etc.) under certain high-season conditions. Chemical pollution levels are less significant.

c) Pollution control options include retaining grey water aboard for subsequent pump-out, restricting boating densities in sensitive locations at appropriate times, and doing nothing (i.e. there is no significant problem).

d) Grey water can be totally retained for all contributing fixtures, or partially retained for the major contributor - galley sink.

e) Variations in the pollution scenario include location of recreational waterway, boating density, boat type, and extent of proposed grey water retention.

f) Recreational waterway sensitivity extends from lowest in the Great Lakes system to highest in a small quiet bay scenario involving maximum boating density in high-season.

g) Boating density may be as high as 70 vessels anchored in a small quiet bay.

h) Boat types are houseboat, power cruiser, and sailboats, i.e. any vessel having overnight sleeping accommodations.

i) Pollution level is highest from a houseboat which typically has the most people aboard.

j) Other pollution contributors include out-of-province pleasure boats, commercial boats (freighters), industrial firms, municipalities, cottagers, and others.

k) The interested groups in the grey water pollution issue include individual boaters, houseboat rental firms, cottage associations, recreational water users (swimmers), environmentalists, naturalists, and others.

l) Existing North American legislation restricting grey water discharges is more the exception than the rule. However, there is evidence that this is changing, i.e. certain jurisdictions such as New Hampshire and New York have recently imposed restrictive legislation.

m) Implications of any restrictive legislation would include:

- increased boater costs for initial installation, and for subsequent pump-outs.

- enforcement enhancement

- modification of certain existing pump-out facilities to accommodate greater loadings, and construction of new pump-outs where required.

7.0 RECOMMENDATIONS

7.1 GENERAL

The detailed investigations into the characteristics, quantities and effects of pleasure boat grey water reported on in this study indicate that relatively high levels of bacterial contamination of Ontario recreational waters will occur in sensitive areas during high-season periods in summer where excessive densities of pleasure boats are experienced.

7.2 RECOMMENDED APPROACH FOR POLLUTION REDUCTION

7.2.1 Grey water discharges from pleasure boats having overnight accommodation should be restricted as follows:

- full grey water retention for all new pleasure boats and all larger existing houseboats in all waterways
- partrol grey water retention for other existing pleasure boats on designated sensitive waterways.

7.2.2 Sampling and Analyses Programs

Field sampling and analyses programs should be initiated as soon as possible to confirm bacterial contamination levels in appropriate areas in representative sensitive waterways. These programs should be carried out during the summer high-season to establish background bacterial levels of representative receiving waters when boat densities are maximum, and to determine the actual characteristics of boat grey water discharges by sampling and analysing grey water from galley, washbasin, etc. on typical houseboats, power cruisers and sailboats.

7.3 IMPLICATIONS

For the recommended approach, there will be implications for boaters, houseboat rental firms, marina operators, pump-out operators, regulatory agencies, and others.

a) Boaters

Restriction of grey water discharges will impose some increased cost to boaters for the required additional plumbing and for more frequent pump-outs of their holding tanks.

It will be important to inform all concerned parties, particularly boaters, of the characteristics of boat grey water in order to gain some degree of acceptance on the suitability of the proposed restriction on boat discharges.

b) Pump-Out Facilities

Although there is a large number of public and private pump-out stations (over 300) in Ontario, it is apparent that many are periodically out of service, access is difficult (particularly late in the boating season when water levels have fallen), and pump-out costs are relatively high. The need to review the adequacy of existing pump-out facilities is indicated to confirm adequacy for sewage (black water) removal from boats, and to determine the extent of additional facilities required to provide for boat grey water removal in the future.

In the United States, before an individual State can restrict the overboard discharge of sewage from pleasure boats, the Federal EPA must be satisfied that adequate pump-out and disposal facilities exist - in order that an unreasonable hardship is not imposed on boat owners.

c) Public Information, Inspection, and Enforcement Programs

It will be important that all concerned parties be made aware of the impact of boat grey water discharges on the quality of recreational water so that public and private support can be enlisted for enhancing pollution reduction objectives. An information program should be formulated and directed at boaters, boat manufacturers, marina and rental operators, and other groups as appropriate.

Previous boat inspection programs carried out by the MOE confirm that boater compliance with present sewage discharge regulations is widespread in sensitive areas of Ontario waters (ref. Item 2.8). Continuing these annual inspection programs in sensitive waterways would permit monitoring and enforcement of the proposed grey water discharge regulations at the most important locations.

Enforcement of grey water discharge regulations would be possible in a manner similar to the existing sewage discharge regulations, i.e. by formal amendment of the Environmental Protection Act; monitoring of boat builders, rental operators, marina operators, etc. By carrying out inspections of black and grey water plumbing systems at the same time, additional inspection staff requirements and administrative costs would be minimized.

7.4 IMPLEMENTATION AND TIMING

Formal implementation of restrictions on pleasure boat grey water discharges would be accomplished by amending the existing Environmental Protection Act to specifically require that:

i) all new pleasure boats and existing larger houseboats in all waterways be fitted with equipment suitable for the storage of liquid wastes from water used for household or hygienic purposes for removal and disposal by shore-based pumping equipment.

ii) all other existing pleasure boats operating in designated sensitive waterways be fitted with equipment suitable for the storage of liquid wastes from water used for household and hygienic purposes for removal and disposal by shore-based pumping equipment.

As previously noted, appropriate public information, inspection and enforcement programs would complement new regulations and encourage compliance by the affected groups.

In order to provide boat owners, manufacturers, etc. with a reasonable period of time to retrofit existing vessels and make the necessary design modifications for new vessels, it is suggested that a reasonable compliance schedule be provided in the revisions to the regulations:

7.5 FOLLOW-ON STUDIES/MONITORING PROGRAMS

The following is a summary of the recommended follow-on study and monitoring programs required to confirm the requirements for reducing bacterial contamination of Ontario recreational waters from pleasure boat grey water, and implement a pollution reduction program, if indicated:

i) conduct water sampling and bacterial analyses programs for representative recreational waters and pleasure boats, as discussed previously in Item 7.2.2

ii) continue annual boat plumbing system inspection programs

iii) review the adequacy and accessibility of existing shore-based boat pump-out facilities in Ontario

iv) review the existing pleasure boat sewage discharge and marina regulations and draft revisions, as required, to provide for restrictions on pleasure boat grey water discharges

v) prepare technical information brochures on boat plumbing system requirements to assist boat owners in retrofittin9 their vessels (hardware description and sources, plumbing system schematics, installation considerations, etc.).

7.6 SUMMARY OF RECOMMENDATIONS

Based on the conclusions of this study, we recommend that:

a) the existing regulations be changed to require:

- full retention of grey water for all new pleasure boats with over-night accommodation, and for all larger existing houseboats on all waterways.

- partial retention of grey water for other existing pleasure boats on designated sensitive waterways.

b) designated sensitive waterways include the Trent-Severn System, Rideau Canal, Lake of the Woods, Bay of Quinte, Muskoka Lakes, and others identified after further review of Ontario recreational waterways.

c) monitoring programs be undertaken in the 1986 boating season to confirm the primary recommendation.

d) pump-outs be upgraded after appropriate study to optimize their suitability for increased loading, to review the issue of excessive fees, and to determine the suitability of government funding for new or expanded installations.

e) guidelines on pleasure boat retrofitting be prepared to assist individual boaters, houseboat renters, and others in cost-effective methods.

f) promotional literature be disseminated to concerned groups on the general rationale and scientific justification for grey water retention.

g) responses be solicited from involved groups before decisions are made regarding changes to the Regulations.

h) enforcement be studied to optimize effectiveness in this historically difficult and sensitive area.

i) houseboat scenario be particularly studied to optimize their utilization and minimize their historic abuses.

j) commercial craft including sight-seeing boats, excursion boats, ferries, etc. be studied further as a separate special category of pleasure boats.

k) regulation of U.S. and other out-of-Province boats be studied further with respect to Ontario's existing <u>sewage discharge</u> regulations and the ramifications of proposed grey water restrictions.

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APPENDICES

(Bound Separately)

A - REGULATIONS - Ontario
- Canadian
- U.S. Federal
- State

B ONTARIO PUMP-OUT STATIONS (1985)

	DATE DUE		